BROWN BOVERI REVIEW

The New Brown Boveri Factory in Birr (Aargau)

This modern factory has been planned for the manufacture of heavy electrical machines, for which it has three parallel bays, 36, 24 and 18 m wide, respectively, and 270 m long. The main bay in the foreground has an overall height of 32 m.

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Farm-land as far as the eye can see. This pleasant pastoral landscape near Birr in the heart of Aargau is where the new Brown Boveri works now stand, the total area of which will be 420 000 m² when fully extended

The rising steelwork of the three main workshop bays already gives an impression of the gigantic proportions of the factory

THE BROWN BOVERI REVIEW

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THE NEW BIRR WORKS FOR THE MANUFACTURE OF LARGE ELECTRICAL MACHINES

TODAY, looking back on the evolution which machines generating electrical energy have undergone in the past fifty years, the most striking feature is the increase in the outputs of individual machines during this period. In 1910 the average unit output of turbo-sets taken into service in Europe was about 6000 kW. By 1930 it had risen to 60 MW; nowadays units producing 100 MW or more have become a matter of course for the project engineers of the electricity companies. In the not-too-distant future this figure may well be expected to increase to 500 MW.

With this evolution, increasing attention had to be devoted in the workshops in which such large units are built to the problems of handling and machining parts which were all the time becoming visibly heavier. In 1927 this growth was catered for in Baden by the erection of a large shop in which large-sized workpieces could be machined and erected. Now, after thirty years, the production facilities thereby provided are completely exhausted. The intense desire to continue to be active in the development of large electrical machines in the future prompted the Company to carry out preliminary studies into methods and means of production and workshop layouts adapted to the typical requirements of the manufacture of large and very large machines. In 1957 building work commenced on the new factory, on a site having an area of 420 000 m², owned by the Company in Birr, about 15 km from Baden. This factory was able to start regular work early in 1960. The orders which are on hand for very large machines will give it a chance of proving its worth from the very start.

(KME) F. Streiff

PLANNING THE FIRST PHASE OF BIRR WORKS

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Apart from the terrain on which it is built and the type of products it will turn out, the arrangement of a new factory is primarily governed by the requirements of production. The present article endeavours to pick out some of the aspects which determined how the factory buildings and production equipment should be grouped in the new Brown Boveri works at Birr. The relationship between the various sections completed in the first phase, within the scope of the general building scheme[1] is explained with reference to a plan. A second plan, showing the floor area of the workshops, indicates the grouping of the machine tools and workplaces.

THE GUIDING principle behind the work of planning the first phase was the fulfilment of the specific requirements imposed on the workshop by the manufacture of large machines. The shops so far completed represent only the first stage in a building scheme for an area totalling 420 000 m². Therefore, for the exploitation of the area covered by the first phase it was necessary to consider factors reaching well beyond this stage alone. Provision had to be made for extending the drainage and transport systems, as well as certain auxiliaries, in order to cope with future development.

Some of the considerations of an operational nature which were decisive for the choice of the adopted shapes and layouts of the buildings will now be briefly outlined.

Production Schedule of Birr Works

From their Baden factory Brown Boveri supply their customers with rotating electrical machines for almost every purpose imaginable. The output scale of these products begins at about 50 W with the f.h.p. motor and extends to the maximum attainable outputs, which for turbo-alternators is nowadays around 500 MVA.

Of these, the generators for propulsion by steam, gas or water turbines, also commutator and induction motors for ratings above 1000 kW, and the heavy traction motors were grouped in Baden under the heading of "Large Electrical Machines". For this department in Birr a new boundary was fixed between the large and medium machines by settling on a minimum weight of 10 tons for a machine. Traction motors were taken out of the group and became the responsibility of the medium group. The weight limit imposed means in practice that all machines in the "large" group must have a rotor diameter of at least 1 m. By deleting these items from the production schedule of the "Large Machine" group, the manufacturing range for Birr becomes more uniform in character and in its quality requirements. This predetermined the clear graduation of the sizes and types of machine tools, which is noteworthy for the uniformity in the manner of operation throughout the factory. This uniformity makes it easier for the workers to adjust themselves more rapidly to new working conditions if they have to be transferred to a different machine from the one to which they are accustomed, owing to the different availability of work for the machines.

Effect of the Shape of Workpieces on the Organization of the Machine-Tool Park

There are many people who choose to liken the manufacture of large machines to bespoke tailoring. This comparison appears convincing as long as it is restricted to the variation in dimensions from one

[1] The overall layout sketched in this article is the outcome of close co-operation between the senior architect Dr. Roland Rohn, Zurich, and factory planning specialists from Brown Boveri.

machine to another and the variety of different components required for their assembly. There may be fundamental constructional differences between the machines of different manufacturers, but when the components of a single firm are examined, it will be evident that there is a similarity in design extending over a surprisingly wide range. This fact is the expression of a crystallized calculation technique gained by the designer from operational experience, as well as being a reflection of the means of production which the workshop has available for the manufacture of the components.

The planning of the means of production for the new factory had to take into account the tradition expressed therein. The machine tools and other equipment of the new shops had to be arranged in such a manner that the Company's traditional designs could be produced economically with them. However, they also had to ensure that, from this direction, the designer's elbow-room is not too severely restricted as regards the realization of new designs.

Trends in Manufacturing Developments

Advances in cutting tools, in the technology of materials utilized in the manufacture of large machines, and in the design of machine tools, provided a forceful incentive for reviewing the production methods of the department handling large electrical machines. This progress is apparent to a most convincing degree, e.g. in the milling of rotor slots. With the machines and tools now available it is possible to reduce the time for milling to 20% of that formerly taken in Baden.

When working with machines which have to be large on account of the size of the workpieces, the problem of non-productive time assumes considerable importance. Machine tools, the acquisition of which involves sums running into millions of Francs, should be engaged for as much of their time as possible on the removal of metal. For the large machine tools a variety of auxiliary devices whose purpose is to reduce the time spent in measuring, in supervising the cutting action of the tools, in tool-changing and in setting up workpieces, were evolved in collaboration with the suppliers of the machine tools. In order to render the operation of the tools less sensitive to disturbances, close attention was paid to the grouping of all control and supervisory elements.

In the last fifteen years there have been a number of major new developments in the field of the technology of insulating materials. Some of these materials possess properties which make them extremely interesting for employment as the insulation of individual conductors or Roebel bars for the windings of large machines. However, the realization of the qualitative progress attainable with these materials in the winding field is extremely dependent on a close observation of their properties when subjected to treatment during manufacture. The tolerances of such materials are inclined to be more limited, so that the step from trial manufacture to industrial processing of these materials to form winding insulation only became possible when specially adapted workplaces and equipment were installed. In the new factory the processing of the classical insulating materials has also been given a "new look" by improvements in the transportation system and the machinery of the winding shop. Here experience gained from the construction of small and medium batches has been put to good use, without the adoption of modern means affecting the well-tried methods in any way.

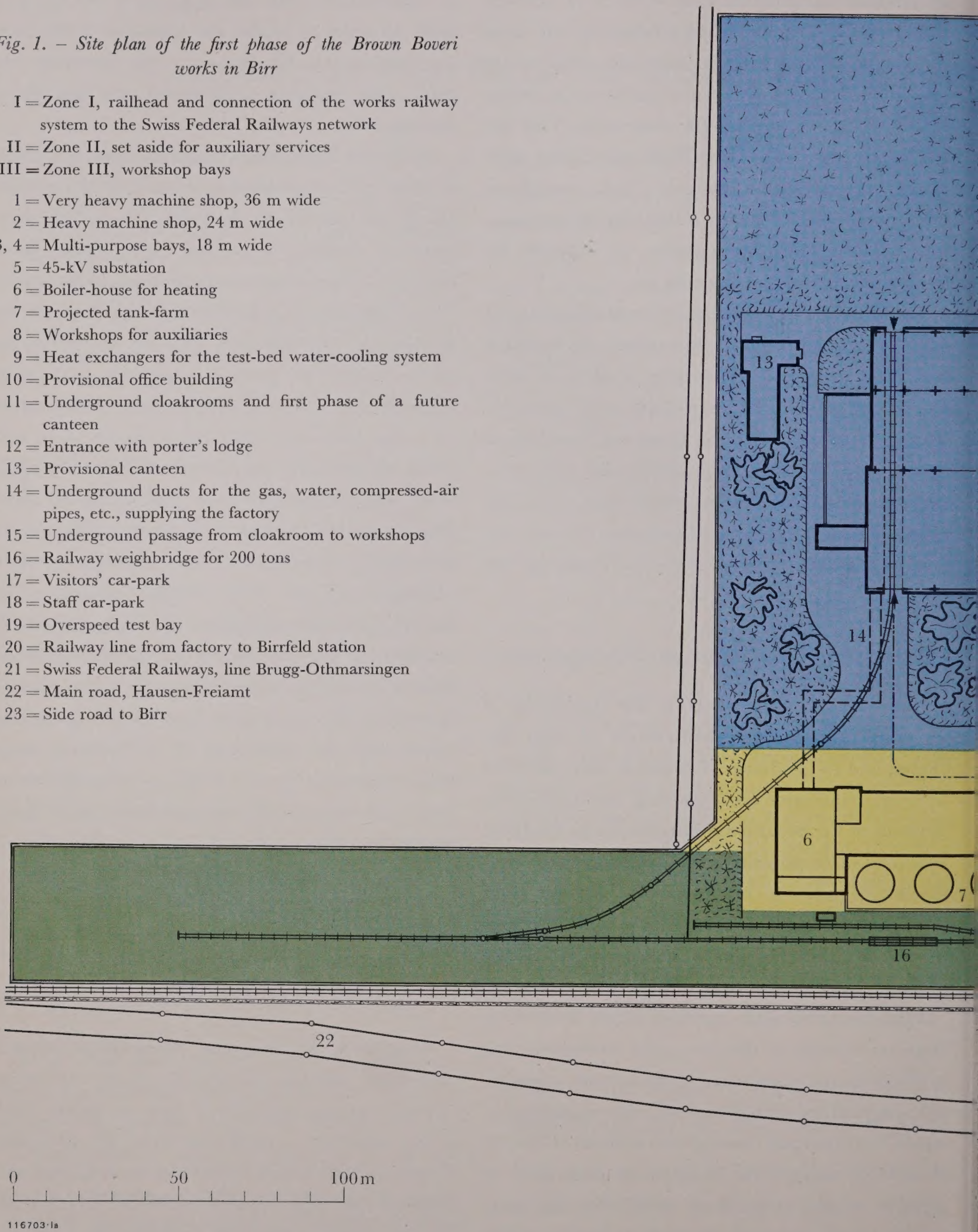
Reciprocation between Production and Workshop

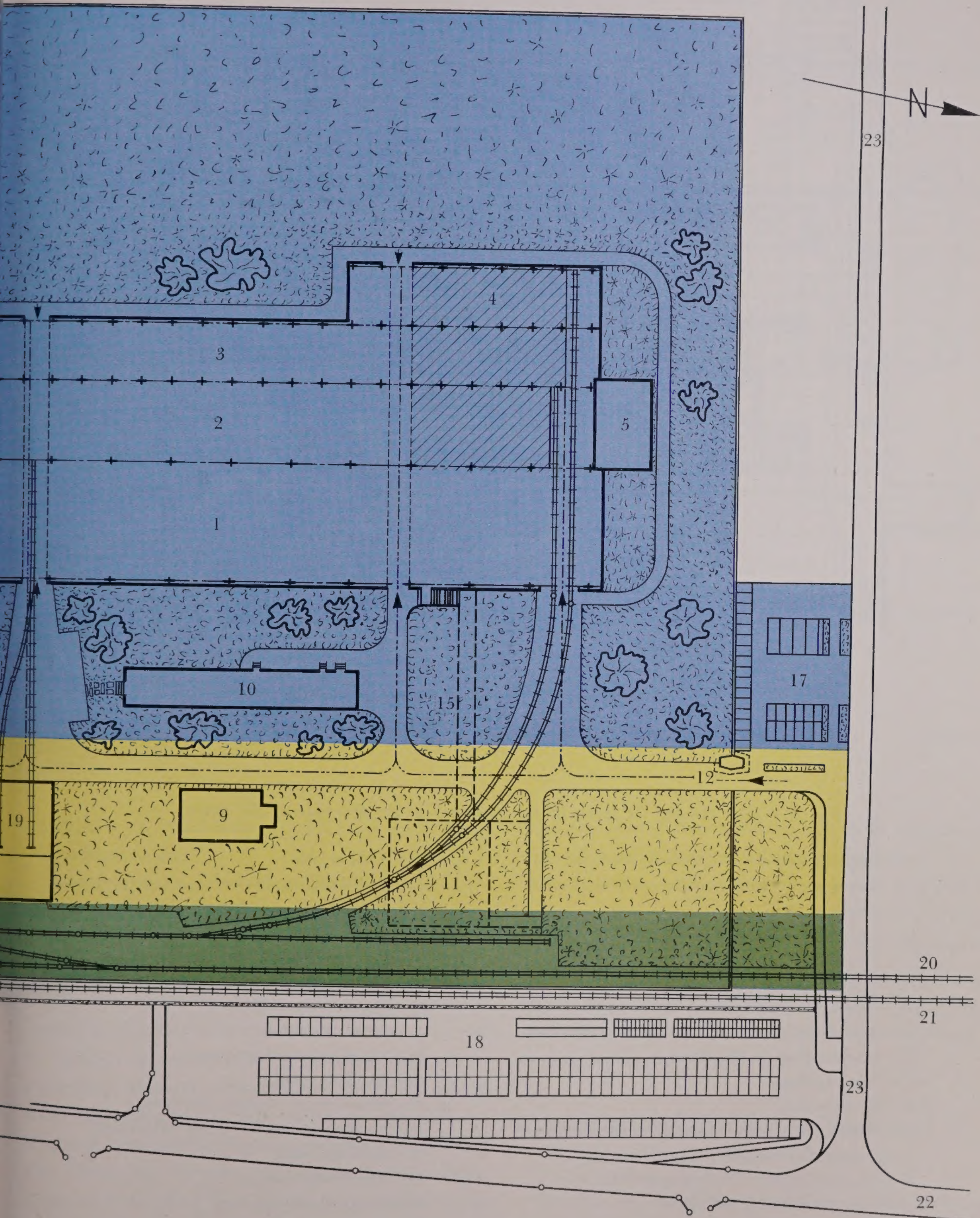
That there are reciprocal relationships between production and the buildings in which it is carried out is borne out most clearly by a workshop which is too small for a particular series of operations. Continual need to shift workpieces around, enhanced accident risk, and transference to the erection site of jobs which should be done in the workshop are only some of the unwelcome repercussions of

Fig. 1. – Site plan of the first phase of the Brown Boveri works in Birr

I = Zone I, railhead and connection of the works railway system to the Swiss Federal Railways network
II = Zone II, set aside for auxiliary services
III = Zone III, workshop bays

1 = Very heavy machine shop, 36 m wide
2 = Heavy machine shop, 24 m wide
3, 4 = Multi-purpose bays, 18 m wide
5 = 45-kV substation
6 = Boiler-house for heating
7 = Projected tank-farm
8 = Workshops for auxiliaries
9 = Heat exchangers for the test-bed water-cooling system
10 = Provisional office building
11 = Underground cloakrooms and first phase of a future canteen
12 = Entrance with porter's lodge
13 = Provisional canteen
14 = Underground ducts for the gas, water, compressed-air pipes, etc., supplying the factory
15 = Underground passage from cloakroom to workshops
16 = Railway weighbridge for 200 tons
17 = Visitors' car-park
18 = Staff car-park
19 = Overspeed test bay
20 = Railway line from factory to Birrfeld station
21 = Swiss Federal Railways, line Brugg-Othmarsingen
22 = Main road, Hausen-Freiamt
23 = Side road to Birr

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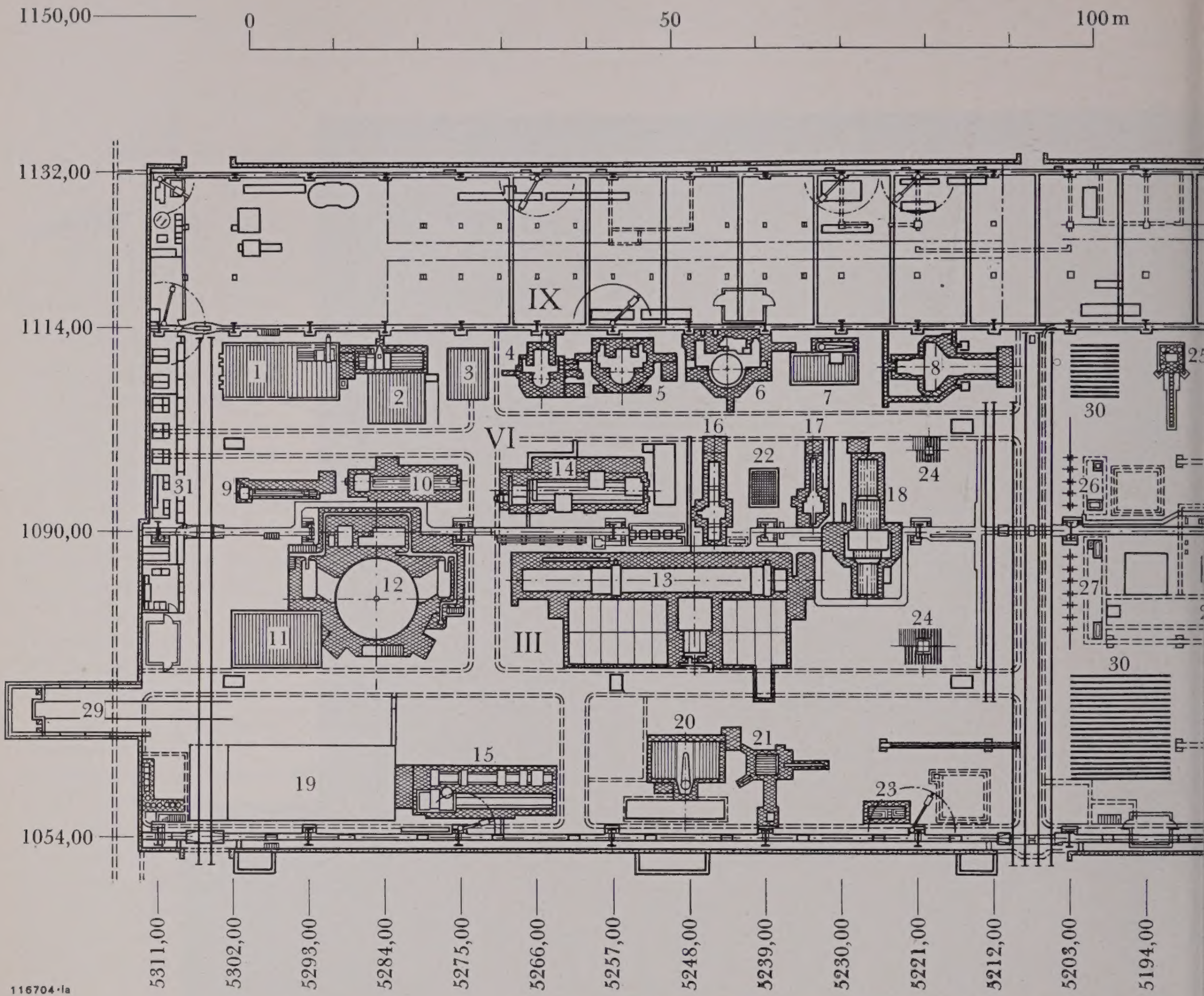
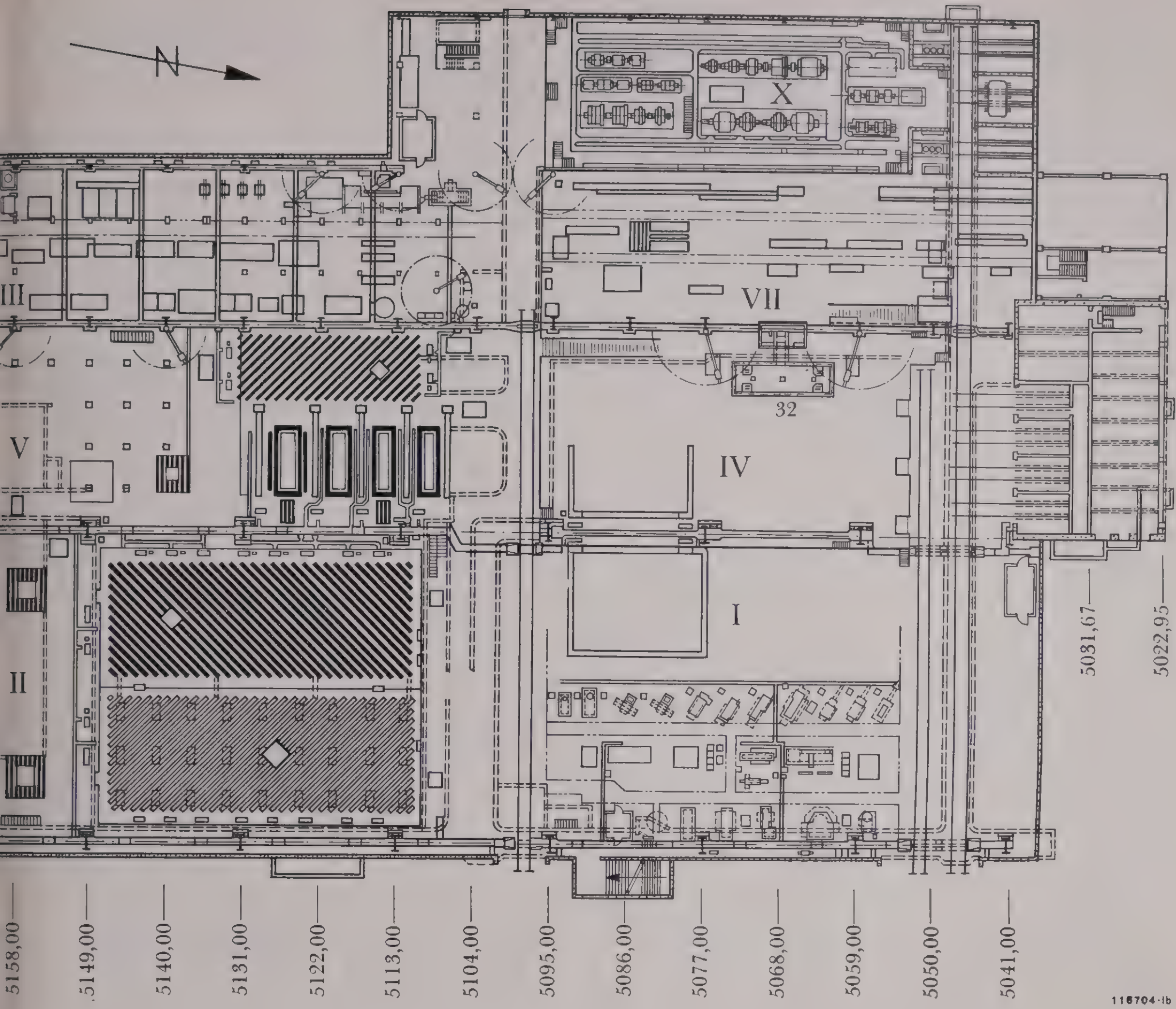


Fig. 2. – Plan showing the layout of the workshops in the first phase of Birr works

I = Despatch section for very heavy machines, containing a provisional machine-tool shop for small components
II = Assembly section and test bed for very heavy machines
III = Machine-shop for very heavy workpieces
IV = Despatch section for heavy machines
V = Assembly section and test bed for heavy machines
VI = Machine-shop for heavy units
VII = Winding shop
VIII = Winding shop
IX = Winding shop with impregnating plant for synthetic resin insulation
X = Machine-house for the testing station
1, 2, 3 = Boring and milling machine
3, 11, 22 = Marking plates
4, 5, 6, 12 = Vertical lathes
7, 20 = Radial drilling machines
8, 17 = Table milling machines
9, 10, 14, 19 = Centre lathes
15 = Rotor-slot milling machines
16, 18 = Planers
21 = Slot-drawing machines
23 = Grinding machine
24 = Shrinking stands for rotors
25 = Hydraulic press
26, 27 = Measurement of stator iron losses
28 = Vacuum furnace for drying turbo-rotors
29 = Sand-blast shop
30 = Lamination stacking
31 = Tool and drawing store
32 = 80-ton weighbridge

The individual bays are denoted by numbers, see text also.



attempting to build large machines in a workshop of inadequate size.

Such relationships between buildings and production, however, are also reflected by the organization of the internal transport and progress-chasing systems and, by no means least, in the formation of the factory hierarchy. If too little or no attention is paid to this factor in a works, this may give rise to deficiencies which, being possibly difficult to recognize, demand compensatory measures which lower the financial profit gained by the factory. The task confronting those responsible for planning Birr Works was to trace such mutual relationships, estimate their effect, and to take them into account in the disposition of manufacturing facilities, the dimensions of the workshops, transport, communications, the form of the organization and the incorporation of auxiliary services in the general plan.

The outcome of the subordinate results and individual considerations, arrived at in the course of the planning work, is expressed in the overall layout of the first building phase, as illustrated by Fig. 1, in which form it was approved for execution. The organization of the whole factory in its separate sections is shown in Fig. 2.

Arrangement of the Various Sections of the First Phase relative to the Site

The site on which the first phase of Birr Works stands already, and on which future extensions will be built, is relatively flat (see coloured plate on

page 375). As far as the terrain is concerned, this site is ideal for industrial building because, under a thin layer of humus, there is an extremely solid gravel bank. According to the geological soundings which were undertaken, this ground possesses the properties necessary for the erection of very large workshops, such as are required for the manufacture of large machines.

Fig. 1 shows the section of the site occupied by the buildings of the first phase. It has an area of about 90 000 m², of which 26 000 m² are already built-up. It is bounded to the north by the public highway from the village of Birr to the west, and to the east by the railway line Brugg-Othmarsingen which runs from north to south.

In principle it would have been equally feasible for the shops to have been laid out north-south or east-west. The main factor which decided in favour of the north-south arrangement was the provision of natural illumination on the shop-floor. With the bays in this direction, and equipped with a saw-tooth roof it was possible to obtain a very uniform illumination in the individual shops. Certain aspects which had to be allowed for in planning the railway track were also in favour of the north-south arrangement. With a relatively small outlay the tracks in the workshops could be connected easily to the outside lines. Later when a ring track is run round the whole of the area, it will be possible to connect the shop tracks direct to the outside line, with the shops running north-south.

The general layout of the first phase is shown in Fig. 1. It can be subdivided into three zones:

Zone 1 contains the sidings and shunting area, which have already been planned for the complete project but, so far, have only been executed for the first phase. Later a ring track will provide a railway service to the whole area from this zone, to which the existing bays are at present connected.

Zone 2 is occupied by auxiliary services. The boiler-house, over-speed test bay, canteens, underground cloakrooms, garages and repair shops of the Maintenance Dept. are all housed in separate buildings in this zone. It also contains the plant supplying the entire area with compressed air, the auxiliaries for the electrical testing station, and a store for inflammable liquids.

The main north-south road through the area, situated east of the factory building and, with a width of 18 m, separating the latter from the auxiliaries, also belongs in zone 2. The supply pipes for gas, water, etc., between the buildings in zone 2 and the workshops run through a system of underground ducts. The exception is the railway line for transporting test objects between the over-speed bay and the workshops.

Zone 3 is the area for the actual factory buildings. In the first phase four parallel shops were erected, covering a total area of 24 000 m².

According to the overall concept, the next step will be to build further workshops to the west of the present ones; these will be for the production of medium-sized machines. South of the present shops a large building will be erected running east-west, in which the raw materials for the large and medium machines will be stored. It will also accommodate a sand-blasting shop and equipment for surface treatment. In principle, it is possible for another shop with a maximum width of 40 m to be built adjoining the east wall. The only wall of the building which is already in its final form, and to which no extensions are planned is the north end. As a fixed annexe to it, there is the first of two substations, from which the factory area is supplied with electricity. This substation, with a capacity of 16 MVA at present, 48 MVA when extended, is fed at a voltage of 45 kV through a cable feeder. For distribution inside the factory 8 kV was chosen, the same as in Baden.

Production Equipment

The wide range over which the sizes of the machines extend, and which still have to be produced, despite the deletions from the department's schedule in Baden, indicated the advisability of splitting production into two separate, parallel lines. Having

Fig. 3. – Bay 36 m wide and 270 m long for the construction of very heavy machines

Looking north from the south end.

regard to the width of the workshops and the load capacities of the cranes, the division between a bay for very large machines and one for not so large machines effected savings in the building costs. The investigations into the capacity of the various workplaces, assuming a total machine weight of 100 tons as the deadline between the two sections, and with the foreseen budget for the delivery of new

Fig. 4. – Bay 24 m wide and 270 m long for the construction of large machines

Looking north from the south end.

equipment, proved that sufficient work could nevertheless be found for the production equipment, even though some of it had to be duplicated. Such duplicated workplaces are necessary if both lines are to turn out their allocated machines without cross-transport from one line to another.

From the calculations which were made, two types of workshop crystallized out as most promising

in relation to the particular requirements. For the construction of the heaviest machines the decision was made in favour of a bay with a width of 36 m, equipped with cranes capable of carrying 150, 60 and 10 tons.

By coupling two cranes together it is possible to lift and transport objects weighing up to 300 tons in this shop. The three different types of cranes run at three levels (see page 448). The construction of machines weighing up to 100 tons is carried out in a bay 24 m wide, equipped with cranes capable of lifting 60, 40 and 10 tons. By coupling two of the largest cranes, the maximum weight which can be lifted and carried in this hall is 120 tons.

Since the size of the building site did not impose any restrictions regarding the length of the shops, it was almost an automatic conclusion for the various workplaces to be arranged successively, conforming to the general sequence of operations performed on the workpieces.

Although such a layout does not create a "production line" in the strictest sense of the term, the successive layout of the facilities for machining, subassembly, final assembly, testing, packing and despatch in the 36-m and 24-m bays does produce a natural sequence which exerts a beneficial effect on the time taken by the product to pass through the shop. One important advantage of the successive layout of the production facilities, especially in the construction of large machines, is that only the workshop cranes are needed to transport workpieces, and they can cover the whole floor area. The length of the manufacturing area from the entry of raw materials to the departure of the finished product, with the layout of facilities as planned, is 270 m, and corresponds to the length of the workshops which have been built. Hence the main dimensions of the two largest bays are as follows:

Very heavy machine shop (Fig. 3):

Width between centre-lines of pillars	36 m
Length between extreme pillars	270 m
Height to underside of beams	23·9 m
Spacing of pillars	18 m

Heavy machine shop (Fig. 4)

Width between centre-lines of pillars	24 m
Length between extreme pillars	270 m
Height to underside of beams	15·8 m
Spacing of pillars	18 and 9 m

A bay of the third type houses the winding shop and the machine-house for the testing station. When the building is extended in a westerly direction, additional bays of the same size are visualized, in which an extension to the winding shop and the department for machining small components will be accommodated. The dimensions of this bay are as follows:

Width between centre-lines of pillars	18 m
Length between extreme pillars	270 m
Height to underside of beams	9·3 m
Spacing of pillars	9 m

A basement is provided beneath this bay, as will also be the case with subsequent bays of the same size. The space is utilized for the storage of partly-finished components. The basements will also contain the air-raid shelters.

The layout of production facilities is basically the same in the 36- and 24-m bays, as can be seen in Fig. 2. The raw material is brought in by rail at the southern end of the bays, at point 5302·0. In the first 99 m of the bay from south to north, up to point 5221·0 are the machine-tool sections III and VI; following them are the assembly sections II and V between the points 5203·0 and 5104·0. In the 36-m bay the erection bed is located between points 5149·0 and 5113·0. This erection bed is equipped with all the necessary facilities, e.g. electricity, oil and cooling-water supplies for test objects. In the space provided it is possible to carry out trials with the largest units in this bay. The corresponding testing section for the 24-m bay is situated between the points 5131·0 and 5113·0. In contrast to the 36-m bay four test beds are provided here, especially for testing turbo-generators of small and medium ratings.

At the north end of the two workshop bays are the despatch sections I and IV. As a provisional measure the despatch section I at present contains a machine-tool shop for small parts, which really belongs in an 18-m bay. This shop will be transferred as soon as the factory is extended westwards.

As a result of the available length of 270 m, it was also possible to effect a logical operational sequence in the winding section. If the principle of successive workplaces were adhered to strictly, though, a length of 350 m would be required. Consequently in the 270 m length it is necessary for a certain amount of reversal to take place. In contrast to the machine bays, production in the winding bay commences at the north end. It passes through the sections VII, VIII and IX, reverses after impregnation and wrapping, and is completed at the point where the winding is assembled with the machine.

(KME)

O. Köhli
P. Frey

PLANNED LAYOUT, TAKING A WINDING SHOP AS EXAMPLE

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The effects which a certain arrangement of the workplaces in a workshop has on the space requirements, transit time of workpieces, etc., are often difficult to visualize in the planning stage. When the production equipment for Birr works was being planned, it was necessary to resort to investigations on models in some cases. The present article describes a typical case.

WHEN A WORKSHOP layout which appears practicable on paper differs appreciably in the arrangement of production facilities from another layout known from practical experience, the assessment of its performance by calculation is subject to certain restrictions. The amount of work involved would be considerable in those cases in which the operational procedure is dependent on certain factors which tend to vary in wide limits. Admittedly this work can be reduced by resorting to simplifications, but then the possibilities of making errors increase very rapidly. When planning the Birr works it was necessary to carry out an investigation on a model in such cases, endeavouring to reproduce the operational factors as faithfully as possible. The experience so gained proved the importance of reproducing all objects involved in the investigation exactly to scale, in order to make a proper assessment of the space conditions.

The results of calculations for a whole series of layout investigations for the first phase of the Birr works, including the dimensions of the bays, were checked with the aid of such models. In order to judge the effect of almost inevitable compromises, such model investigations are indispensable.

An example of a typical check investigation will now be described, the object being to determine what effect a newly introduced transport system has on the conditions in a winding shop. The model investigation is capable of providing all kinds of important information.

For transporting the material within the winding shop at Birr the most suitable of several alternative methods proved to be the palette system. This system is insensitive to rearrangement of the workplaces it has to serve, and it also affords excellent facilities for stacking. It was most difficult to estimate the space required by such a system, because the volume of material which has to be carried is influenced to a great extent by the proportions of work on hand for turbo-machines and hydro-electric generators. There was therefore a risk of over-dimensioning the space for the transport system, particularly because the length of the stator bars which have to be carried affects the space occupied and supports the tendency to over-rate the requirements.

The primary object of a functional check was to investigate the question of space requirements in

greater detail, considering the factory with different loads. Of secondary interest was the investigation regarding the number of times the overhead crane would be required by a system of this kind. The utilization of the space was examined for the following load conditions:

1. Space occupied by palettes for a manufacturing schedule with turbo- and hydro-electric generators in the proportions assumed for the production capacity on which the project was based.
2. Space occupied by palettes for a schedule with extreme loading by the manufacture of hydro-electric generators.
3. Space occupied by palettes for a schedule with extreme loading by the production of turbo-machines.

Elements Used in Performing the Check

Model of the Shop

A three-dimensional model of the shop being investigated was made to a scale of 1 : 50, with all details exactly in position according to the proposed layout (Fig. 1). Therein the foreseen dimensions of the individual workplaces and storage areas are limited. The investigation in this case was confined to the shop along the 1114·0 line, in which the bars are prepared.

Fig. 1. – Scale model 1 : 50 of the bar preparation section in the winding shop at Birr

Representation of the Individual Workplace

Fig. 2 shows the model of a workplace, which in this case is divided into three parts:

(*a*) Palette with material to be handled,
(*b*) Palette with finished material,
(*c*) Workplace at which the operation is performed.

Auxiliary Media Representing the Material and Time Spent Handling It

To simplify matters the material which has to be handled at each workplace was represented by a sheet of paper, on which the most important information regarding the material and the operations to be performed are noted. On the right-hand palette in Fig. 2 a "load ticket" of this kind can be seen. An order to produce, say, 576 stator bars belonging to a generator type WV 560/24 would run through the winding shop divided up into twelve palette loads. With the dimensions of these particular bars, each palette can carry 48 bars; the palette on the right in Fig. 2 is the eleventh and thus holds bars 481–528. These bars have to pass the operations bending, painting with zinc oxide, etc., the time allowed for execution of the operation being 12 hours, 18 hours, and so on.

The time unit chosen for these model investigations is one hour. This is denoted by a round wooden

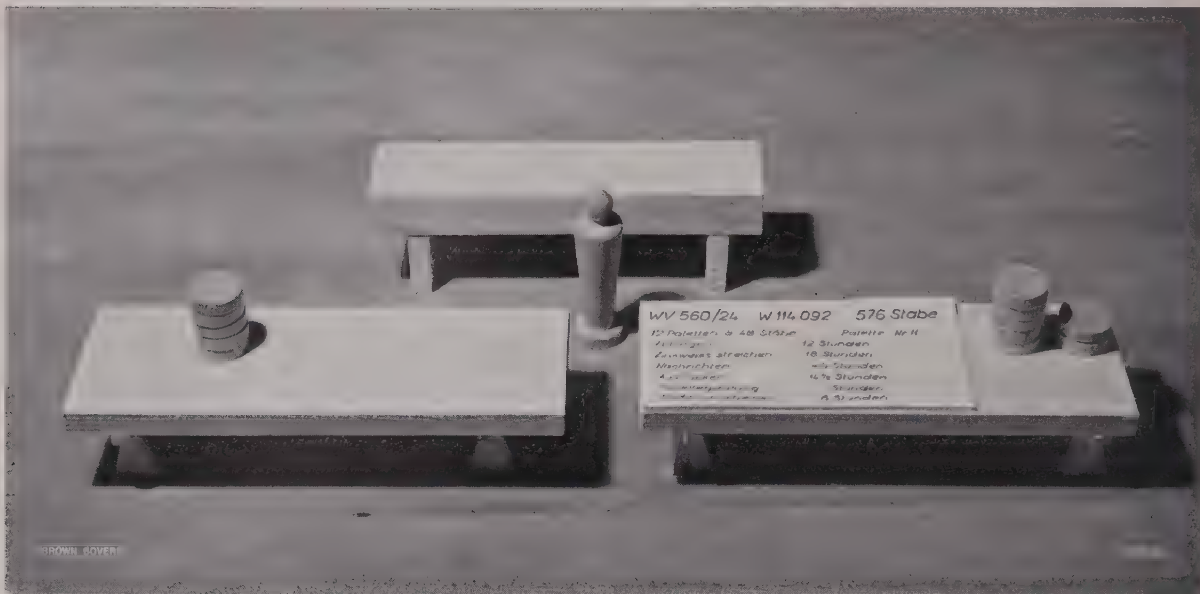


Fig. 2. – Model of an individual workplace

disc, or counter, as can also be seen in Fig. 2, in which five of the twelve hours' operation time have already elapsed. Five counters are on the left-hand palette which receives the material handled at the workplace depicted. The work still to be done is sufficient for the remaining seven hours; hence seven counters are on the right-hand palette carrying the material still to be processed. The ticket representing the "palette load" is transferred to the left-hand palette with the last disc.

Carrying Out the Investigation in Practice

In conformity with the set task, three alternative production programmes were considered for the investigation, utilizing the standards mentioned above, corresponding to the basic plan, and with the extreme proportions of hydro-electric to turbo-machines.

A feature common to the three schedules investigated is that in each case the material is drawn from and delivered to an intermediate store, that is to say the commencement of work on the various jobs does not have to pay heed to processes which, from the general aspect, take place before or after the section being investigated. Hence one palette after another could be set in circulation exclusively in accordance with the progress of work within the particular section. From the moment 0—representing the start of work at the first workplace—one counter was shifted from the unfinished to the finished palette of each pair in circulation, at the end of each hour. When the last counter was removed from the palette with unfinished material, the work at that particular workplace was considered finished, and the palettes ready for shifting onwards to the next place. After about 300 such time-units had elapsed from the moment 0, an occupation of the shop characteristic for this programme was finally reached.

Results Gained

Occupation of Floor Area

The floor areas occupied with production facilities, as determined by these investigation are shown in the Table opposite. When comparing the figures it must be borne in mind that for individual operations in the section investigated, palette is synonymous with workplace.

	Production programme corresponding to capacity on which project was based	Production programme with extreme load due to construction of hydro-electric generators	Production programme with extreme load due to construction of turbo-machines
Floor area occupied by production facilities	423 m²	378 m²	464 m²
Floor area occupied only by palettes	146 m²	104 m²	180 m²

Occupation of Crane, Transit Times

In the example under discussion we are interested not only in the mere numbers of square metres as given in the Table but also the frequency with which the overhead crane has to operate for transporting palettes in the winding shop, and the anticipated fluctuation in the transit times of the products handled in that section. The record kept during the investigation was drawn up in the form of a Table and includes corresponding remarks columns. The evaluation of these records gave a mean number of six operations per eight-hour shift for the crane carrying palettes. The maximum number of operations was 19 in the same period. Allowing an average of four minutes for each operation, the crane in the winding shop investigated is in practice engaged on carrying palettes for an average of 24 minutes and for a maximum of 76 minutes per eight-hour shift.

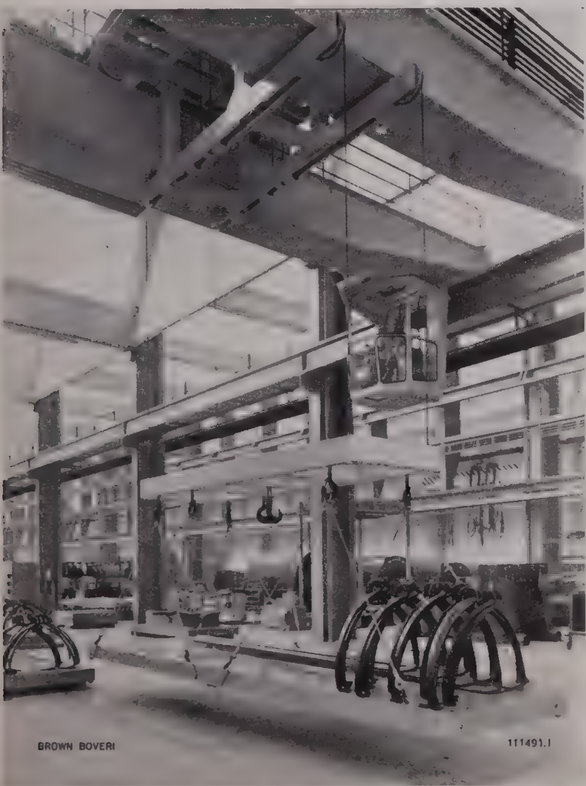


Fig. 3. – A transport palette loaded with bars in the winding shop at Birr

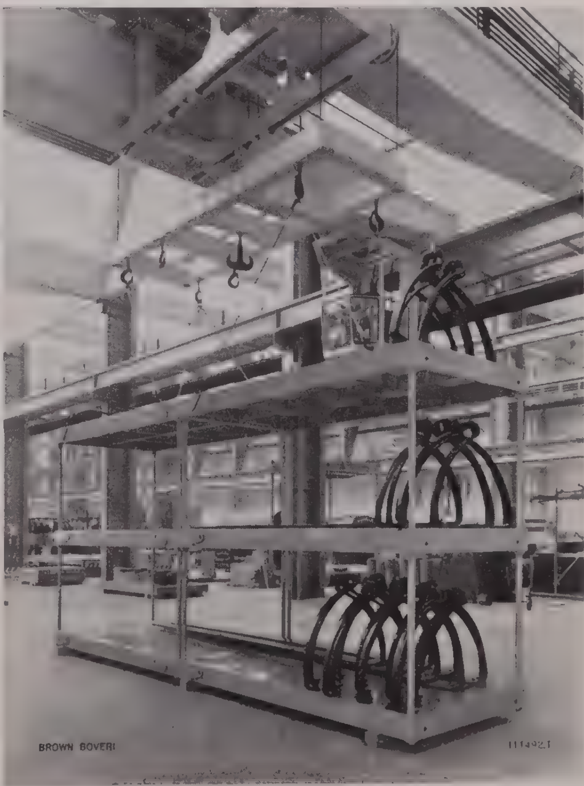


Fig. 4. – Stacking palettes to form an intermediate store before the assembly of the winding

The notes made regarding the transit times resulting from the trial run, assuming single-shift working at eight hours per day, show that to complete a whole job the transit time may be expected to fluctuate between a minimum of 18 days five hours and maximum of 53 days one hour.

Effect of Changing the Programme of Work

In practice it will sometimes be impossible to avoid sudden changes in the programme of a production section, due to external circumstances. The effects of such a change were investigated with the same model, assuming one order to be held up in the section and another given priority at the same time. From the results of these investigations it was possible to draw valuable conclusions regarding stacking of palettes; they also indicated the extent of loss of production caused by such interruptions to the programme. The tests also showed that such model investigations can be used to examine the necessary measures involved when changes have to be made to the programme, with a minimum loss of production.

The introduction of the palette as the standard means of transportation within the winding shop necessitates matching the palettes to the peculiarities of the transport vehicle and material carried. To carry the palettes forward, as already stated, the overhead crane is used. The features peculiar to the material are the different lengths of the bars and, in connection with the coil-ends, the lack of uniformity in the distribution of the weight in individual groups of windings.

For the winding shop in Birr simple metal palettes were devised, which can be used singly or joined together, being lifted by the crane hoist and thus transported. Fig. 3 shows a combination of two such palettes suspended from the crane. Fig. 4 depicts the manner in which an intermediate store is formed by stacking. The palettes can be stacked on top of one another with a minimum of expense, and a stock held at any point of the floor for a limited period.

(KME) O. KÖHLI

THE LARGE MACHINE TOOLS IN BIRR WORKS

621.9

The most important large machine tools installed in Birr works are described in this article, which also gives the reasons underlying the choice of particular machines. The sections devoted to individual machines contain remarks on the opportunities for employment of these machines, their control systems, and the measuring and protective equipment.

THE BASIS on which the large machine tools were planned was the general workshop layout for the large objects which the factory is intended to turn out. Machining processes were studied in detail with different types of machine

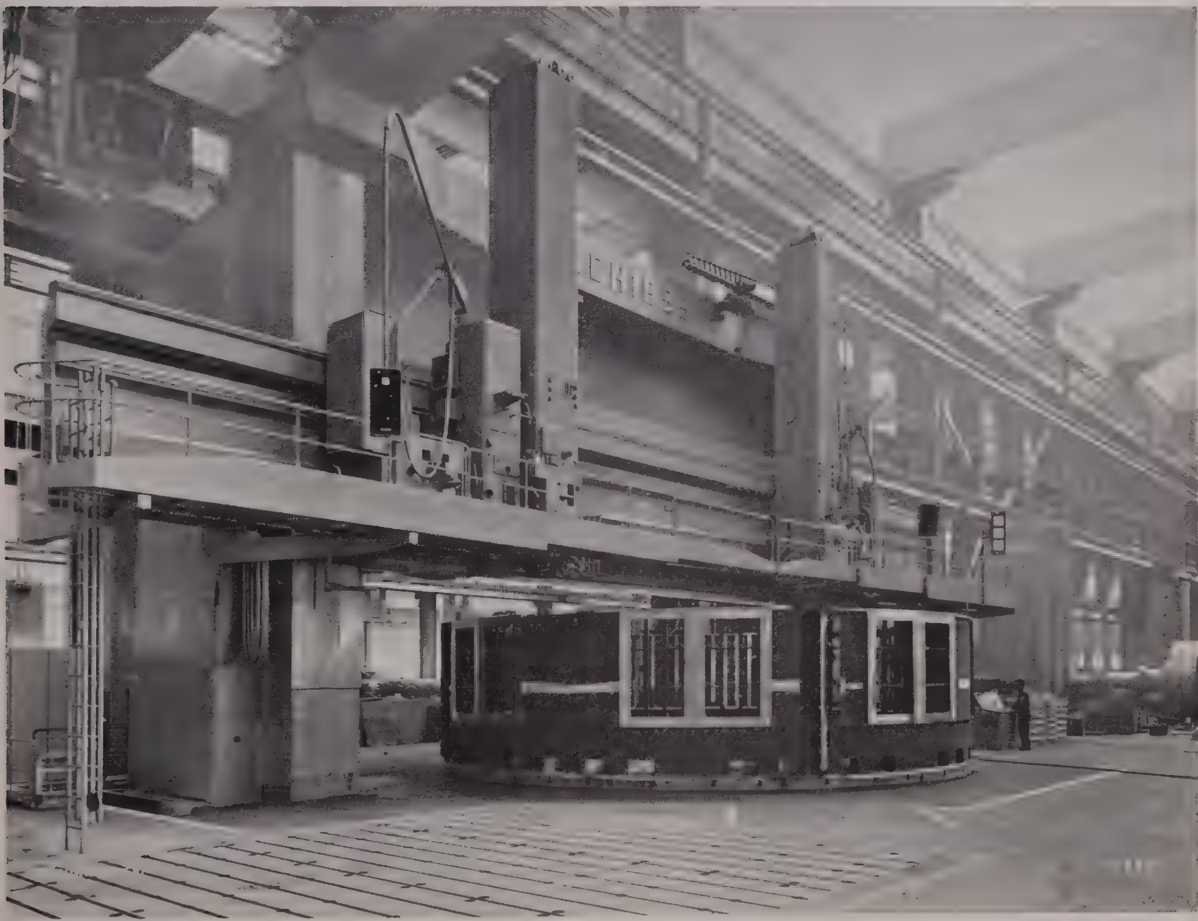


Fig. 1. – Large vertical lathe (Schiess AG., Dusseldorf, Germany)

The stator of a hydro-electric generator is mounted on the annular face-plate, ready for machining.

Max. turning diameter	14 m	Speed of annular face-plate	0·08–10 rev/min, infinitely variable
Max. turning height	6·1 m	Speed of inner face-plate	0·19–24 rev/min, infinitely variable
Diameter of annular face-plate	10 m	Max. admissible load of annular and inner face-plates	270 t
Diameter of inner face-plate	5·5 m	Weight of machine appr.	800 t
Ram extension	3·7 m		

Fig. 2. – Rubbing down the guide-ways for the annular face-plate of the vertical lathe

tools, using completed parts in the course of manufacture, and future designs. Since there was no need to make allowance for existing machine tools in this case, decisions could be made freely and favourable solutions thus obtained. The main task was to exploit all experience gained in the past by Brown Boveri in this sphere, so as to be able to machine large objects in the future, improving the quality of the products, reducing unproductive and machining times, and simplifying assembly by eliminating finishing work. From the investigations, the final choice was centred on the following types of machines: Large vertical lathes, boring and milling machines, rotor-slot milling machines, centre lathes, slotting machines and large radial boring machines. These machines, the first four of which will be described, are installed in the main, high bay. Their positions can be seen in the plan view on pages 382/3.

Large Vertical Lathe

Since this machine has to deal with high objects, on the one hand, such as the stators of turbo-generators, which are small in diameter but up to 6 m long and, on the other hand, stators of hydro-electric generators and l.p. turbine cylinders which are low in height but very large in diameter, it was equipped with a high-speed inner face-plate and a low-speed annular plate (Fig. 1 and 2). Due to the large difference in height of the workpieces, a simple means of raising and lowering the cross-beam had to be provided. The cross-beam itself is 23 m long and in three sections, together weighing 150 tons. To comply with the strict requirements regarding the high accuracy of machining, and in order to be able to machine large workpieces almost to the centre, the choice fell on fixed pillars. The

highest point on the machine is 15 m above the workshop floor. Despite this appreciable height, not only the 150-t crane, but also the 60-t crane can ride above the lathe unhindered.

The enormous foundations for this machine were the subject of a special investigation (see the article on page 407). The machine rests on 125 adjustable supports, by means of which subsequent deformation of the machine can be corrected, if necessary. But not only high geometrical accuracy had to be attained; better means had to be found for setting and measuring dimensions on the machined workpiece. With former conventional methods the inaccuracy can be quite considerable with very large diameters, and measurement takes an unduly long time. Therefore a completely new approach was adopted. With the new type of optical measuring system it is possible to adjust the cutting steel accurately to the desired point and to keep a check on the machined diameter (Fig. 3).

The versatility of the large vertical lathe was enhanced by various measures. The right-hand cross-head has a copying system with a wide operating range. In the left-hand cross-head is a milling unit with provision for adjusting the angle of the cutting spindle, for facing and circumferential milling. It is intended to incorporate a copying system for frame milling and milling any straight surface parallel to the face-plate. The machine is also equipped with a pick-feed and indexing system for the face-plate. By inclining the ram and coupling the vertical and horizontal motions through gear wheels of different sizes it is possible to turn cones of any desired taper.

The feed rates of the cross-head and ram are steplessly derived from the face-plate speed through selsyns, and can thus be adjusted to the correct rate per revolution. The high-speed traverse can be carried smoothly down to the creeping speed, thus almost eliminating manual adjustments. The position of the cross-beam can be adjusted finely by motors. All motions other than those preselected are automatically locked.

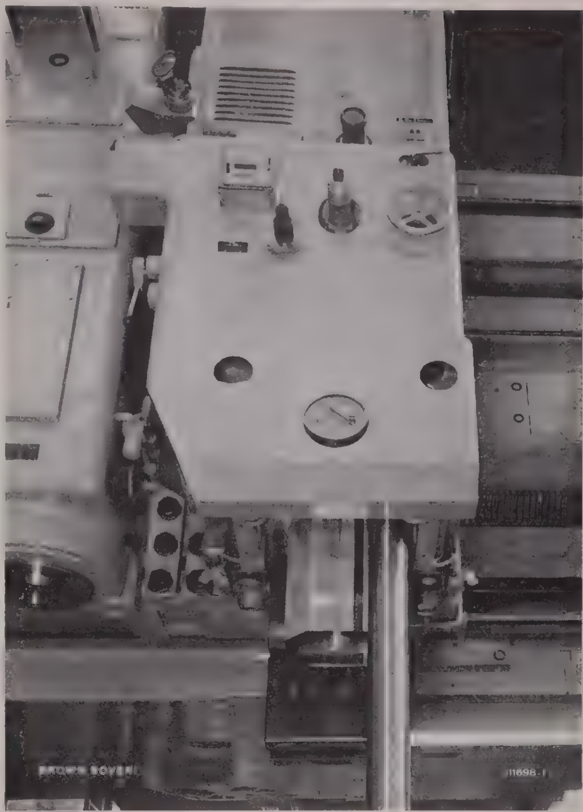


Fig. 3. – Measuring system on the cross-head of the vertical lathe

Middle: sight for cutting tool
Bottom: light and lens of sighting device
Left: optical reading of dimension on the cross-beam scale, visible top right

The quality of machining, the state of the cutting steels and the exact positioning of the tool can be observed through a closed-circuit television system. A minicamera mounted in the tool-holder is connected to a pair of monitors, one on the control desk and the other on the carriage (Fig. 3 and 4). By this means the tool inside the bore of the workpiece can be observed and accurately adjusted from the control desk. Work on the tool-holder with the ram fully extended used to be a tedious business on former machines. This difficulty is overcome by a motor-driven cage in each cross-head (Fig. 5), with a travel of 4 m, enabling the machinist to travel from the platform into the workpiece with the associated pendant control unit. Since the cage is also pivoted, it can be used when external surfaces are being machined. The measures described greatly

Fig. 4. – Control desk of the vertical lathe

from which all important commands are given, with instruments and television screen at the top for supervising the action of the cutters.

reduce the unproductive times, which on large machine tools can become quite appreciable.

To attain a high standard of reliability and prolong the life of the machine tools, special attention was devoted to the lubrication; above all for the heavily loaded slideways, where the oil film is completely broken down when the machine stands still for any length of time. Thus, for instance, before the face-plate starts to move, a film of oil is forced into the slideways at high pressure, the latter being adjustable from the control desk according to the weight of the workpiece. On the cross-heads oil is only supplied automatically to those points at which movement is taking place. Thermocouples supervise the temperature in the face-plate bearings. The load on the centre-shaft of the inner face-plate can be measured electrically. A pivoted hoist attached to the crane can be used to lift the lighter accessories on to the machine from the point where they are stored.

Milling and Boring Machines

Mounted on a common bed are two milling and boring machines. Between the two base-plates is a turntable accessible to both machines (Fig. 6). This arrangement with two pillars on a common bed and a turntable between them was chosen from a number of proposals examined. This grouping renders the machines extremely versatile, and allows one workpiece to be set up while another is being machined. This eliminates lengthy unproductive times since the two units can be employed almost continuously. The larger machine (Fig. 7) is primarily used for heavy milling and boring, while the smaller performs combined milling and boring jobs. The main purpose of the turntable is to reduce the time spent in setting up and to improve the machining accuracy in different planes. It is equipped for

Fig. 5. – Machinist in the cage inside the workpiece with the suspended control unit

On the tool-holder of the ram is the miniature television camera (not visible in the photograph).

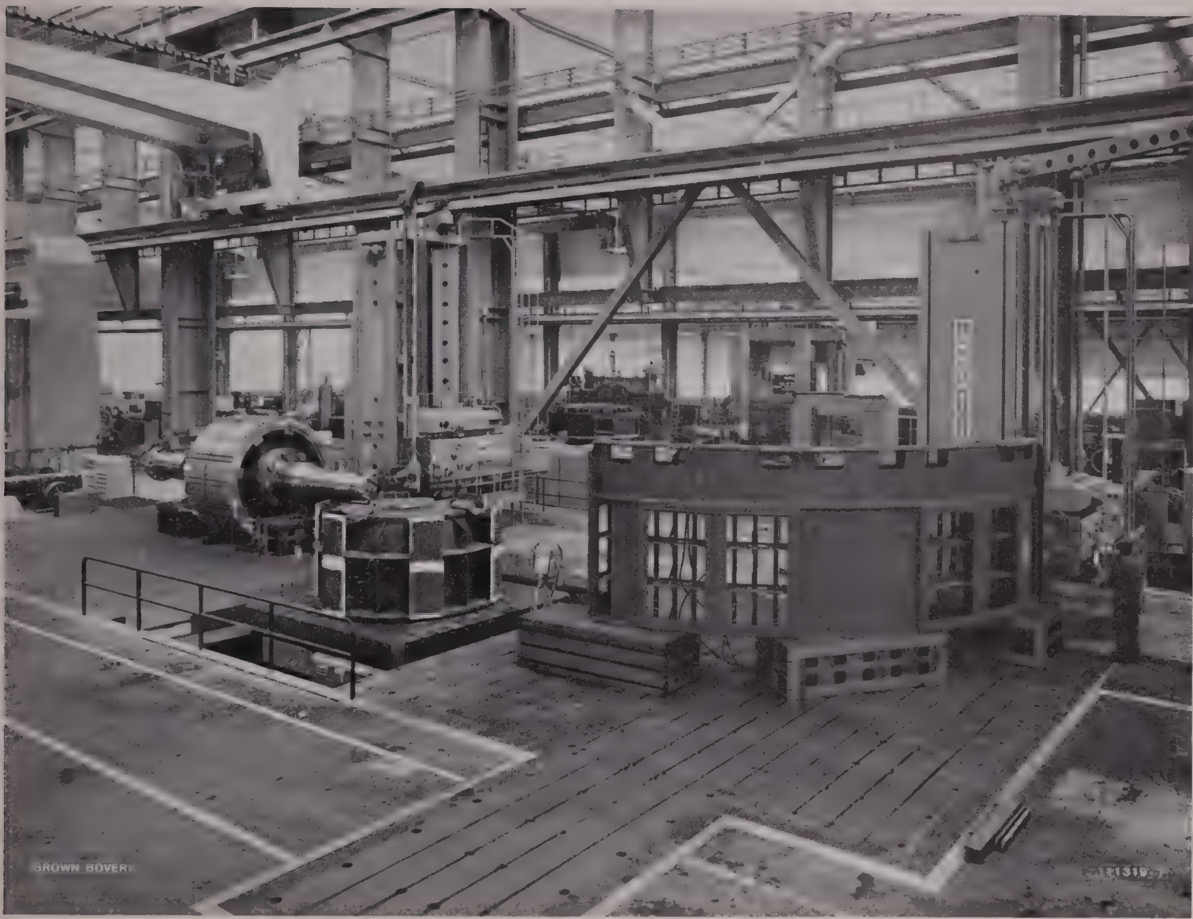


Fig. 6. – Milling and boring machines (Made by Innocenti, Milan, to the design of C.W. Berthiez, Paris)

Both machines run on a common bed. Between the base-plates is the turntable.

Large milling and boring machine (left)	
Vertical travel of headstock	5 m
Longitudinal travel of pillar	21 m
Diameter of boring spindle	20 cm
Projection of headstock	1 m
Projection of boring spindle	2 m
Speeds infinitely variable	from 1·6 to 445 rev/min
Feed speed infinitely variable	from 0·064 to 1700 mm/min
Drive power of spindle	45 kW

Small milling and boring machine (right)	
Diameter of boring spindle	147·5 mm
Projection of headstock	75 cm
Projection of boring spindle	1·5 m
Spindle speeds infinitely variable	from 2·6 to 640 rev/min
Drive power of spindle	30 kW
Other data as for large machine	

Turntable			
Clamping area	4·25 × 4·25 m	Max. load	100 t
Longitudinal travel	3 m	Base-plate left	12 × 8 m
		Base-plate right	8 × 8 m

indexing, cross milling and peripheral milling and, owing to its high indexing accuracy, permits the workpiece to be reversed and machined from the opposite side. The bed, which is accessible beneath covering plates, is 30 m long overall and rests on a total of 200 adjustable supports. The spindle's deviation from the straight over the entire longitudinal travel is within a few hundredths of a millimetre in the horizontal and vertical planes. For adjusting and checking the geometry of the machine, face-plate and turntable, optical measuring devices were adopted. With the aid of a precision telescopic

Fig. 7. – Large milling and boring machine being used for the stator of a hydro-electric generator

The machine is controlled from the power-driven control unit on the right.

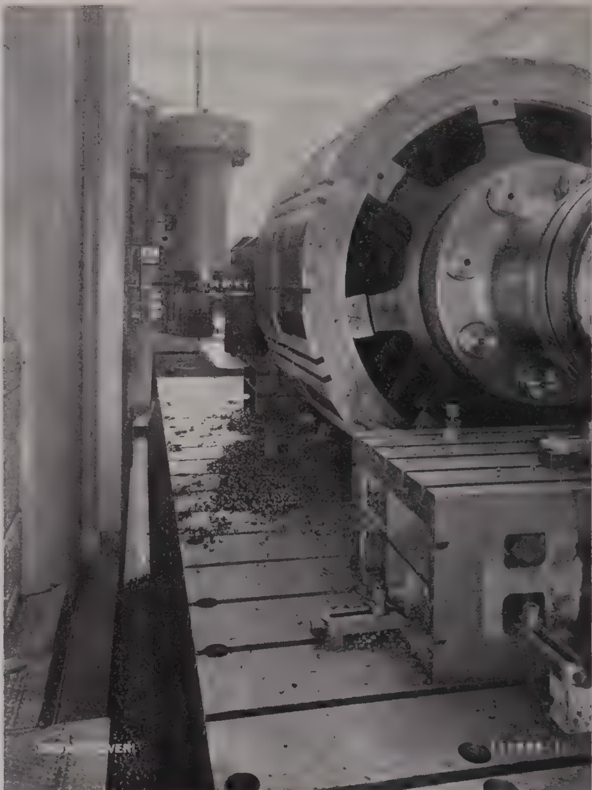


Fig. 8. – Angled milling head with tungsten carbide cutter of the milling and boring machine being used for the preliminary milling of a rotor slot for a hydro-electric generator

Swarf falls into a vibrating channel between the machine and bed-plate and is automatically conveyed to a container.

sight, a suspended mirror and pentagonal prism, it was possible to measure alignment, levelness and inclination with great accuracy. Constructional safeguards ensure that the headstock runs out perfectly horizontally. The machines are easily controlled from a suspended control unit (Fig. 7), adjusted by a motor. All important control commands can thus be given from a convenient point, there is no need for measurements to be adjusted by hand. The positioning devices for all movements, aided by cams, result in a repetition accuracy of within 0·02 mm. The elements which are not in motion are locked by automatic, hydraulically operated locking devices, which do not break down the oil-film on the slideways.

For changing the tool and accessories, each machine is equipped with a crane. A vibrating channel between the face-plate and bed (Fig. 8) disposes of the swarf, dumping it into containers at the end of the bed. The current and cooling medium is carried by a cable chain.

The two face-plates, 12×8 m and 8×8 m, respectively, on which the workpieces are clamped, consist of individual sections $4 \text{ m} \times 2$ m. The area covered by the entire group is 36×20 m, the weight of the foundations belonging to it 4300 tons.

Rotor-Slot Milling Machine for Turbo- and Hydro-Electric Generators

For milling jobs on the rotors of large turbo-alternators and hydro-electric generators, and for various special milling tasks, the machine depicted in Fig. 9 and 10 is used. As Brown Boveri were probably the first manufacturers to employ tungsten-carbide-tools for milling small rotors—about seven

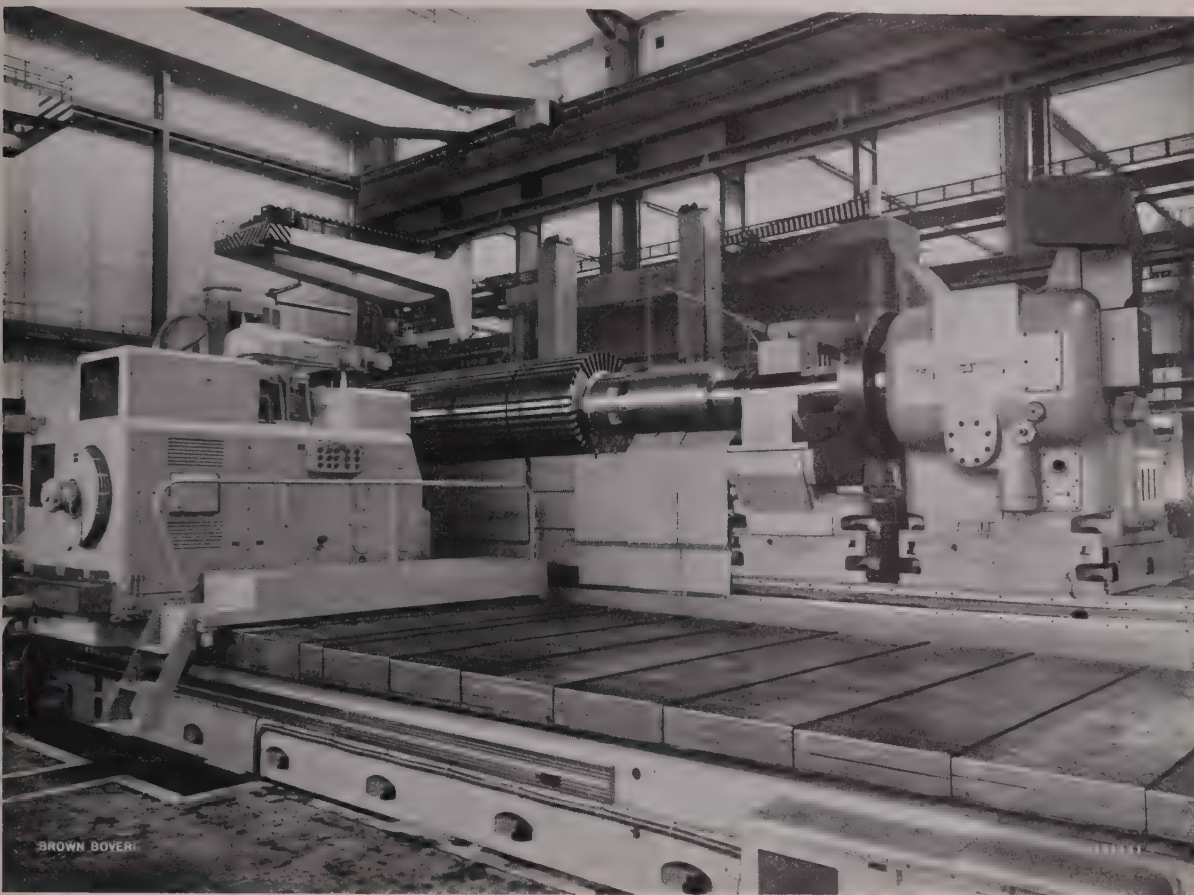


Fig. 9. – Rotor-slot milling machine (Gebr. Heller, Nürtingen, Germany)

Left to right: Heavy milling headstock, rotor, clamp and indexing gear; in the foreground, the covered slideways.

Max. milling length	11 m
Max. diameter of workpiece	2·5 m
Heavy vertical milling unit	
Milling spindle diameter	320 mm
Max. cutter diameter	1120 mm
Speed, infinitely variable	8 to 70 rev/min
Feed rate, infinitely variable	10 to 700 mm/min
Drive power	120 kW

Horizontal milling unit	
Milling spindle diameter	160 mm
Speed, infinitely variable	18 to 450 rev/min
Max. cutter diameter	600 mm
Vertical travel	1000 mm
Two-spindle milling head	
Spindle diameter	60 mm
Speed	80 to 1800 rev/min

years ago—the decision was made to extend this method to the large rotors. In the place of the old double-sided machine with high-speed steel cutters, the new rotor-slot milling machine is only single-sided. Doubts regarding the suitability of one-sided milling proved to be unfounded after investigations had demonstrated that there were no changes in the rotor. Whereas formerly the maximum attainable feed rate was 15 mm/min, it is now possible to employ a feed rate of 250 mm/min for roughing. Thus for a rotor with a slotted length of 4500 mm, the time for milling a pair of slots has been reduced from ten hours to about 1½ hours. Furthermore the unproductive times are greatly reduced on the new machine.

All cutting units are combined on a common cross-slide (Fig. 11). The slots are produced by the heavy vertical milling unit, fastened at the top, with milling wheels having a normal diameter of 950 mm. The outer support and tail spindle adjustment permit

Fig. 10. – Rotor-slot milling machine, rear view

Left to right: Indexing gear, clamping and supporting pedestals.

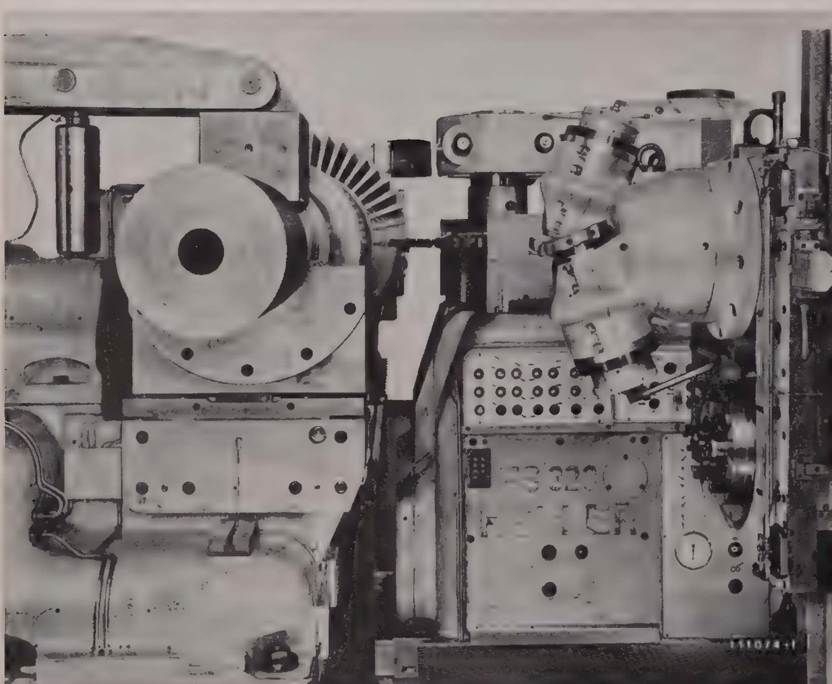


Fig. 11. – Milling cross-head of the rotor-slot milling machine

Right: Crossed slot-mouth cutter and double-spindle milling head with control platform and heavy vertical milling unit.

Left: Rotor with front clamp.

slots to be machined up to 180 mm off-centre. Next to them on the common cross-slide are two horizontal milling units with a large transverse and vertical shift, for the different easier milling tasks, such as the mouth of the slot, shaft extension and for facing, as well as for a number of special tasks. The normal slot mouths of 60° and 70° are machined with a crossed pair of disc-type tungsten carbide milling cutters. There are also a number of supplementary heads to allow for future progress in design. With a double-spindle milling head, one spindle of which can be revolved round the other, end-on cutters can be used for two-sided cutting up to any slot width. Slots machined with tungsten carbide wheels exhibit a high surface quality and maintenance of tolerances, which is particularly marked at the mouth of the slot.

Special attention was devoted to the clamping and indexing systems (Fig. 10 and 11). Indexing the rotor is effected by a hydraulic system. A glass indexing disc marked with the slot spacings is coupled with the rotor being machined. The markings are projected on to a screen, enabling the machinist to control indexing from the control platform between the two milling units. Two self-locking hydraulic clamps with interchangeable bearing shells hold the rotor firmly in position. Three supporting pedestals prevent it from sagging and vibrating while it is being machined. All clamping actions are controlled electro-hydraulically from the control platform. The indexing system is also equipped for copying work.

During the forward motion the slots are completely milled at a speed of 300–700 mm/min, and the mouths during the return motion of the slide. As a result of the centralized control of all movements, the use of switch dogs and automatically raising the cutter, this high-output machine can be operated by only one man.

In order to be able to machine rotors of hydro-electric generators, as well as turbo rotors, the machine was made higher than usual. In spite of this the useful life of the tools has not suffered.

The amount of swarf produced per hour is extraordinarily large, in fact for roughing it is around 450 kg. The swarf is caught by a vibrating trough below the cutter, conveyed to the left-hand end of the machine, where it is dumped in a container. During roughing, the average power consumption is about 60 kW; the heat produced is almost all dissipated in the swarf, the rotor body hardly becoming warm at all.

Centre Lathe

For machining turbo rotors the design of this lathe with a four-track bed had to be specially adapted (Fig. 12). Sliding on the two front tracks are two cross-heads. The left-hand upper cross-head is equipped with a copying system, allowing longitudinal and surface copying to be carried out. The left-hand cross-head is also equipped for thread cutting, the necessary speed take-off from the headstock being provided by a selsyn. The other feed rates are also provided steplessly by selsyns with mechanical speed-change gears. The cross-head and headstock are controlled from a desk mounted on the cross-head where the machinist stands and gives all commands for direction, feed, fast return and for the spindle. Adjustment of the cutting radius is improved by optical aid. The workpiece is clamped by means of hydraulic cylinders.

Lubrication of the guides is performed as a function of time and distance, only those guides being lubricated on which movement is taking place, preliminary lubrication being effected when the direction is selected. When the heavily loaded front spindle bearing starts, a high-pressure lubricating system comes into action. The tailstock has a revolving dead-centre capable of withstanding 80 t. The supporting thrust is indicated on a scale, an alarm being set off if the pressure becomes too high.

Special attention was paid to the back rests, a completely new method being adopted in their design. Running on the two rear tracks of the bed

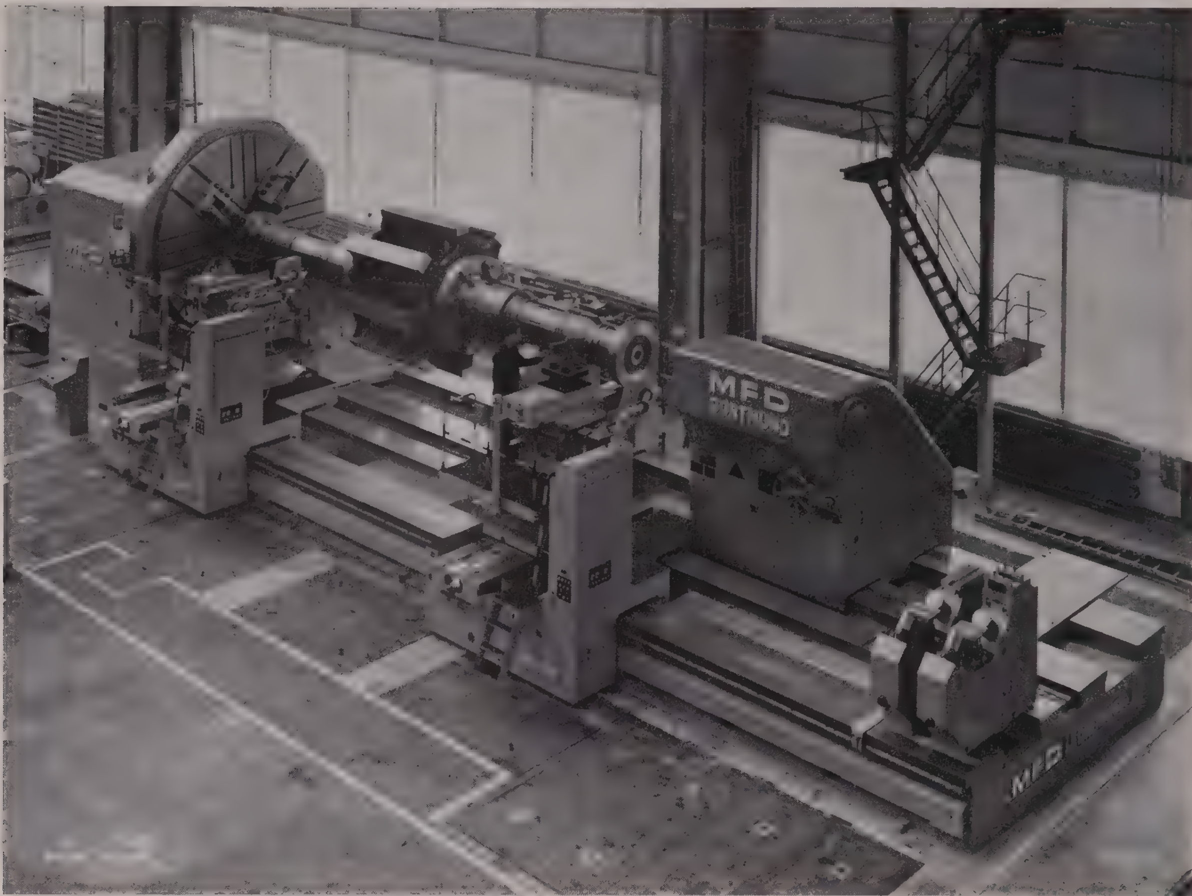


Fig. 12. – Centre lathe (Maschinenfabrik Deutschland, Dortmund)

Centre height above bed	2·2 m	Diameter of front bearing	650 mm	Load between centres	150 t
Max. distance between centres	14·5 m	Speeds, infinitely variable	0·4 to 64·8 rev/min	Drive power	80 kW
Turning diameter over bed slide	3·8 m	Headstock load	75 t	Max. cutting force	15 t

are the two back-rest undercarriages, on which the three interchangeable rests are mounted. The vertically moving supporting rest takes up most of the load, and has circulatory oil lubrication. The two side spindles are only lightly loaded but are used for guiding and positioning the workpiece. This allows higher speeds and tungsten carbide tools to be used; furthermore, the shaft is perfectly centred. Measurement is simplified by the provision of a mobile measuring platform on the back-rest track. The swarf is deposited in containers recessed in the front part of the bed.

Obviously when large new machine tools are purchased on this scale, there has to be close co-operation between the manufacturer and the user. Many innovations and improvements were suggested by Brown Boveri and subsequently incorporated. Large machines, which formerly were difficult to manage and required several machinists, can now be controlled quickly and reliably by a single man. The quality of the articles produced with these machines will continue to improve, indeed only since they have been available it has been possible to produce such large objects.

(KME) H. WEGMÜLLER

THE ELECTRICAL EQUIPMENT OF THE NEW MACHINE TOOLS AT BIRR

621.9–83

The employment of large machine tools in the new factory at Birr gave Brown Boveri an excellent opportunity to put into practice some of the experience gained in the field of drive techniques. Whereas the preceding article dealt with mechanical aspects and the applications of four different types of large machine tools, the present contribution is devoted to the electrical equipment of the drives and controls of these four large machines.

THE FOUR large machine tools described in the preceding article may be regarded as some of the most interesting features of the new Birr works, not only from the mechanical point of view, but from the electrical too. The initial exchange of views between the specialists responsible for the electrical equipment took place at about the same time as the first sod was cut on the factory site. The first task was to decide on the overall layout of the electrical equipment, the positions of the main converters and switchgear, as well as planning the cable ducting, without being restricted by an existing building layout. The final details were discussed at a much later stage. Today, now that the factory is in operation, it is obvious that this preliminary planning was well worth while.

In close collaboration with the machine designers, the factory engineers and the drive specialists, the electric drives were developed, with special attention to the stipulations regarding ease of operation, both from the electrical and operational aspects. At the same time the latest experience in the sphere of electric drives was incorporated, in order that these large machines may fulfil the conditions imposed on them in years to come. For operation of the machines an arrangement had to be found, by which unproductive times could be reduced to a minimum. The choice of the most suitable materials and the skilful design of the switchgear guarantee a high standard of reliability with easy maintenance. Some of the most interesting features of the electric drives will now be described in detail.

The Large Vertical Lathe

As described on pages 394–6, this machine has an inner face-plate and an outer ring, each of which is separately driven by a Ward-Leonard d.c. motor with a rating of 130 kW at 460 rev/min. The connections of the main drive are such that each motor can run independently, and both can be coupled to drive the whole face-plate. A thyratron system for regulating the voltage of the Ward-Leonard generator, in conjunction with a quick-acting voltage regulator (Fig. 1) for weakening the fields of the main motors, is responsible for controlling the speed and ensuring that the starting and braking torques conform to certain preset figures. This system of control is particularly advantageous for facing, because it enables a constant cutting speed to be maintained over a wide range, regardless of the turning diameter.

For the feed drive of the two cross-heads, each with a torque of 7·5 mkg, which have to be shifted at the same time as the face-plate, a kind of selsyn is employed, consisting of a Ward-Leonard motor with converter and magnetic amplifier, and a pair of tacho-generators for the comparison of actual value and desired value. With supplementary potentiometers it is possible to effect fine control of the cross-head feed between the individual gear

Fig. 1. – Thytron Ward-Leonard control system of a variable-speed drive rated 2 × 130 kW, on the large vertical lathe (Schiess AG., Dusseldorf)

The electronic control system regulates the voltage of the Ward-Leonard generator, the regulator (left) weakening the fields of the two variable-speed motors via a field-weakening machine.

stages; these potentiometers also influence the high-speed cross-head movements, which can then be controlled so accurately that fine adjustment by hand is superfluous.

For operating the machine it is equipped with two pendant control units, which are easily moved to the most convenient point for the machinist. A control desk (see Fig. 4 on page 396) beside the machine contains the necessary push-buttons and instruments, especially those for supervision of the lubrication. The lubricating points on the face-plate are continuously scanned by an electrical system and any defects immediately indicated by a flashing light.

The Milling and Boring Machines with Common Turntable

The milling spindles and all feed motions of the cutters and turntable are driven by d.c. motors with the classical Ward-Leonard control. In conjunction with multi-stage speed-change gears these produce wide, infinitely variable speed ranges for the cutting and feed spindles, thus enabling the most suitable speed to be chosen for every task. The feed drives are also equipped with a corresponding gear combination for fast and slow traverse. A special design was stipulated by Messrs. Innocenti for the variable-speed motors, to match the construction of the machine.

Whereas the converters are installed in a separate room, the switchgear is housed in cubicles immediately behind the machine to which it belongs (Fig. 2). The leads from the converters and switchgear, in contrast to the normal arrangement with pillar and hanging cable, are taken to the milling and boring machine by means of a cable chain, thus eliminating the obstacle which would be created by a pillar and heavy hanging cable.

The pendant control units can be displaced horizontally and vertically, being driven by electric motors. They accommodate all controls for the spindle and feed drives. Instruments with extended scales allow the speeds of all drives to be set very accurately indeed. The potentiometers for regulating the speed are housed in a separate compartment of the switchgear cabinet and are controlled by push-buttons in the pendant control unit.

The Rotor-Slot Milling Machine

This machine is equipped with variable-speed d.c. drives for the two milling units (Fig. 3). The power for the feed is provided by a hydraulic system. The main milling unit drive develops 120 kW at 1500 rev/min, for the auxiliary cutter the drive power is 30 kW in a speed range from 1000 to 1800 rev/min. Since both cutter drives are never

Fig. 2. – Milling and boring machine built by Innocenti, Milan (under licence from C.W. Berthiez, Paris), with Ward-Leonard drives rated 44 kW at 3000 rev/min for the spindle and 12 kW each at 3200 rev/min for the three feed motions

In front of the machine is the pendant unit with all controls for the machine; on the right are the switchgear cabinets, which also contain some of the equipment for another boring machine and for the turntable.

in action at the same time, a common converter set was provided. It is installed in the converter room below floor level, and is thus protected against dirt. The converter is connected to the drive motor required for a given task by a motor-driven change-over switch when the Ward-Leonard generator is unexcited.

Maximum simplicity in operation was one of the guiding principles when planning the electrical equipment. Thus all push-buttons are of the illuminated type, the execution of a command being acknowledged by the lamp in the button lighting up. The individual push-buttons are mounted in neatly arranged, easily accessible control units. Instead of using lettering, the majority of the operations are denoted by symbols.

All commands imparted by push-buttons and limit switches act on a Heller light-current control system, which conveys them to the power circuits via intermediate relays. In this installation high accuracy in speed and mastery of the acceleration and braking torque of the two variable-speed d.c. drives is attained by a simple control system without any amplifiers, thus allowing the design of the heavy-current part of the switchgear to be extremely simple.

The Centre Lathe

Conforming to the stipulation that control must be as quick and simple as possible, this lathe (see Fig. 12 on page 402) was equipped with a number of auxiliary drives, on account of its large size. It was specified that, from the control platform on the cross-head it must be possible to give all commands required, even for turning complicated workpieces. Thus, for example, a gear change in the headstock or adjustment of the speed of the main drive can be effected from the cross-heads. In order to meet all requirements, each cross-head is equipped with a light-current system of preselector control.

The main drive employs an 82-kW d.c. motor fed from a converter and controlled via an exciter set. With a device specially developed by Brown Boveri the load on the main drive and gearbox during turning can be read off as a percentage, by means of a scale on the headstock. As soon as the main drive is overloaded, an alarm sounds, the machine being shut down after a set time-lag if the overload persists. The equipment of this machine comprises a total of 52 machines with outputs ranging from 50 W to about 100 kW. All feed motions of the two cross-heads are derived from a pair of selsyns;

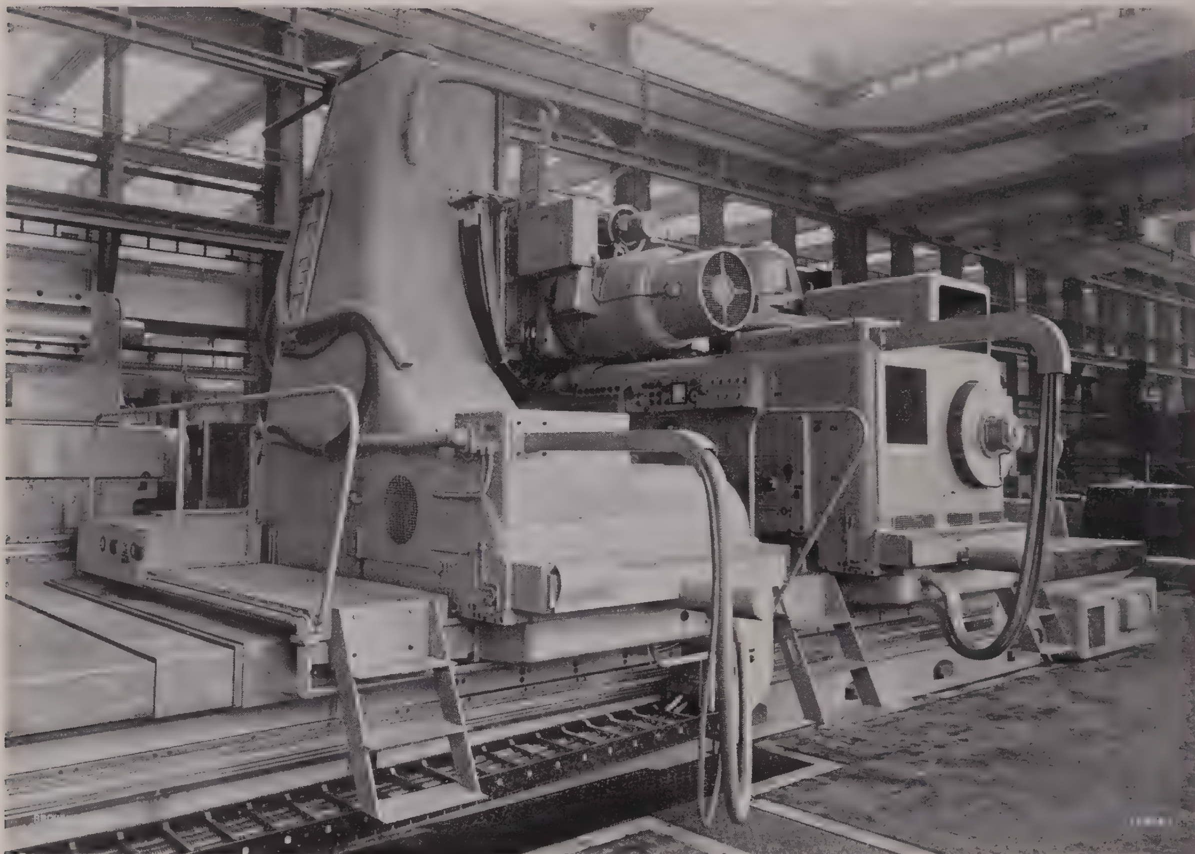


Fig. 3. – Rotor-slot milling machine (Gebr. Heller, Nürtingen, Germany)

The main cutter is driven (right of picture) by a 120-kW Ward-Leonard d.c. motor with a speed of 1500 rev/min. The auxiliary cutter by a 30-kW Ward-Leonard motor with a speed of 1000 rev/min. The control units are equipped with illuminated push-buttons, on which commands can be monitored.

thus all the selected feed rates, with the exception of the high-speed traverse, are governed by the speed of the face-plate. The selsyns are also utilized for thread cutting. Separate motors are incorporated in the cross-heads for the high-speed traverse. By means of electro-magnetic clutches in the cross-heads the selsyns or the high-speed motors can be coupled up for longitudinal movement or facing and for the motion of the pivoted carriage. The preselector control was designed so that, firstly, the type of motion can be selected—longitudinal, facing or pivoted carriage; secondly the direction of motion—outwards, towards headstock, inwards, towards tailstock; and thirdly the commands feed, stop, high-speed traverse, can be given. Every change in the preselector during the sequence causes the "stop" command to be given. All push-buttons are illuminated, the built-in lamp lighting up when the command is executed. Current relays in series with the magnetic clutches supervise the acknowledgement signals back to the push-buttons, to ensure that no faulty operations are allowed to take place. By means of the almost contactless system of light-current control, in which most relay contacts are replaced by selenium rectifier elements, a very high standard of reliability is attained.

(KME)

A. SCHENKEL
M. STEINEBRUNNER
G. FAISS

PROBLEMS OF THE FOUNDATIONS FOR LARGE MACHINE TOOLS

621.9–216/–218

The Problems Posed

ONE OF THE tasks confronting the builders of the new factory in Birr was the design of the foundations required for a large number of heavy machines. These machines could be divided into two main groups, imposing quite different conditions on their respective foundations. On the one hand were the high-speed converter sets in the machine-room which, for constructional reasons, had to be erected on a sectionalized foundation. Here it was primarily the dynamic calculation, rather than the static, which determined the dimensions of the framework comprising the base-plate, supports and table, care being taken to avoid resonance phenomena by ensuring that the natural frequencies of the individual parts and of the whole foundation on its base were sufficiently different from the excitation frequencies of the machines. On the other hand there was the numerically predominant group of large machine tools, upon which this article will concentrate. From the dynamic aspect these may be considered as "steady" machines without any pronounced excitation forces.

For the foundations of machine tools the main problem is that of elastic deformation, which can exert an appreciable influence on the dimensional accuracy of the finished workpieces. Nowadays, with the high standard of engineering, industry is expected to be able to machine workpieces accurate to a few hundredths of a millimetre; but elastic deformation cannot be avoided. Since such small orders of magnitude are involved, not only is the deformation of the foundations an important factor, but also that of all other elements concerned, such as the adjustable supports, base-plate, etc. It is therefore necessary to investigate to what extent these changes of shape affect the machining accuracy and how the sum of these effects can be kept within permissible limits. For this a large milling machine will be considered.

The Soil Conditions

To obtain the basic information for calculation[1] of the foundations for the machines, the soil conditions had to be surveyed in great detail first. Samples taken from all points in the workshop area showed that the subsoil in Birrfeld consisted of firmly packed gravel. But since the excavated depth, due to the basement foundations, was in many cases consider-

[1] By Emch & Berger, Consulting Civil Engineers, Berne.

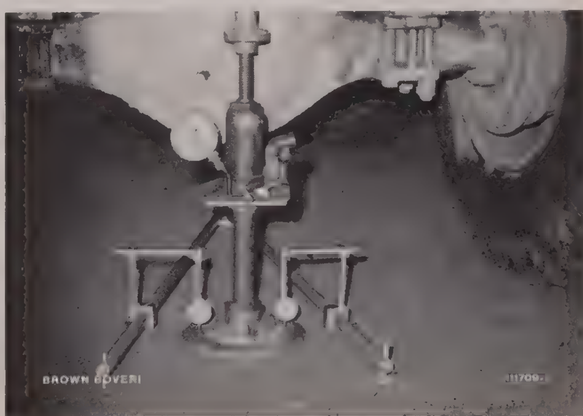


Fig. 1. – VSS apparatus for determination of the relationship between soil pressure and settlement

The large manometer indicates the applied soil pressure while the small meters on their special stands measure the amount by which the plate sinks. The pressure is introduced into the column hydraulically; the lorry acting as counter-balance.

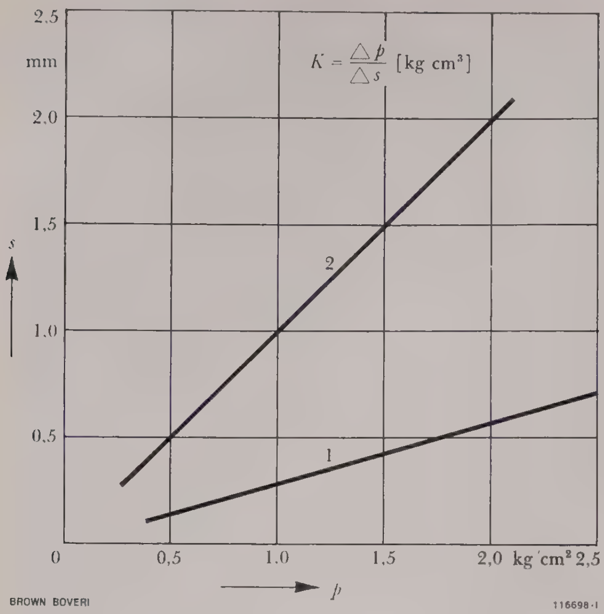


Fig. 2. – Relationship between pressure (p) and settlement (s)

1 = Settlement measured with VSS apparatus, $K = 35$ kg/cm³
2 = Settlement of foundations, $K = 10$ kg/cm³

ably lower than would have been necessary for the machine bases, the latter had to rest on gravel dumped at a later stage, if uneconomical foundations were to be avoided. This dumping was performed in layers 30 cm thick at a time, each layer being compacted by vibrating machines.

The load tests carried out afterwards with the VSS apparatus[2] (Fig. 1) yielded information regarding the admissible soil pressure, the settlement to be expected and the modulus of reaction. K (in kg/cm³), which is defined as the soil pressure causing a settlement of 1 cm, and is largely dependent on the size of the loaded area. The VSS apparatus can be used to measure the pressure and the resultant settlement direct; from these two figures the modulus of reaction can first be found for the 30-cm test plate, from which, employing values gained by experience, the modulus for a large area foundation can be calculated. In Fig. 2 the settlements measured with the VSS apparatus are plotted together with the anticipated settlements for the foundation, as a function of the pressure.

For the foundations, whose pressure was of the order of 1 kg/cm² (roughly 1 t/ft²), these measurements gave an anticipated settlement of 1·0 mm and a modulus of reaction of 10 kg/cm³. Since the weights of the workpieces are relatively small compared with the actual weight of the foundations, subsequent settlement in operation is no longer of any significance.

Deformation

The factory engineers stipulated that, during machining, the inaccuracy in the workpiece introduced by the sum of all possible deformations must not exceed 0·02 mm. In contrast, inclination of the whole foundation, due to uneven settlement, could be considered harmless up to the order of 1 mm. Taking the large milling machine as example, the dimensions of whose foundations and the schematic layout of which are to be seen in Fig. 3, the following considerations governed the dimensions of the foundations.

The following deformations caused by the payload (workpiece) must be investigated:

- Longitudinal sag of the foundation,
- Transverse sag of the foundation,
- Local penetration of the concrete by the supports,
- Elastic compression of the supports themselves,
- Elastic deformation of the baseplate, bed and table.

Longitudinal sag of the foundations

This was calculated with the aid of Hiyashi's beam theory[3] for elastic bedding. Fig. 5 gives an example of the sag curves of the foundations caused by a workpiece at the midpoint of the foundation, one curve being for a modulus of reaction $K = 10$ kg/cm³, the other, by way of comparison, for $K = 5$ kg/cm³. It is obvious at a glance that the magnitude of K does effect the absolute settlement but not the sag of the foundation; in other words any

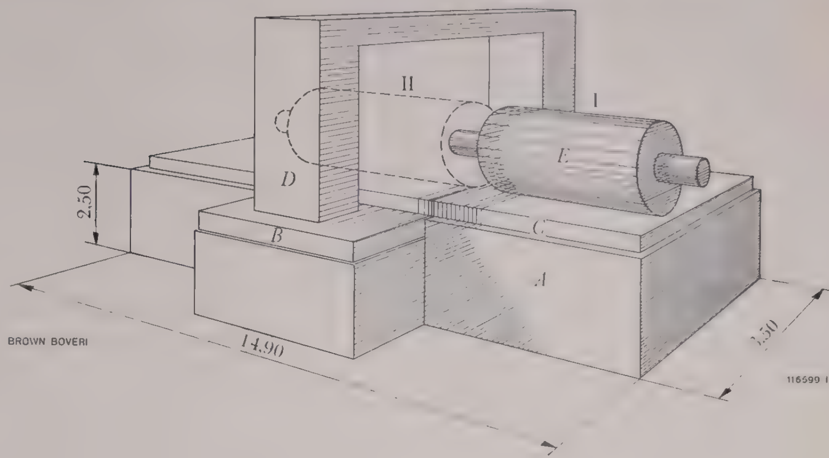
[2] VSS = Vereinigung Schweizerischer Strassenfachmänner. = Swiss Association of Highway Engineers.

[3] KEIICHI HIYASHI: Theorie des Trägers auf elastischer Unterlage. Springer-Verlag, Berlin 1921.

Fig. 3. – Large milling machine with the workpiece in two positions (I and II), shown in perspective

A = Reinforced concrete foundation
B = Base-plate supported by 25 adjustable supports
C = Three-piece bed, supported by 24 adjustable supports and the base-plate B
D = Gantry with milling mechanism; firmly attached to B
E = Workpiece, including table, movable, total weight 58 t

Dimensions in m



uncertainty in the assessment of the soil has little effect on the calculated sag curve.

The following considerations governed the assessment of this curve: The workpiece itself sags a certain amount under its own weight—for instance, the most rigid workpiece sags 0·012 mm over a length of 3·00 m. Now the foundations ought to be just as rigid as the workpiece because then the workpiece is just capable of matching the sag curve of the foundation and the sag cannot influence the machining accuracy. If the foundation is too flexible, it sags more than the workpiece over the length of the latter, so that, relatively speaking, the workpiece rises from the foundation and, for example, a slot milled in a (theoretically) horizontal cylindrical rotor does not follow a straight line parallel to its edge, but an intermediate curve. On the other hand it is also obvious that nothing is gained by making the foundation more rigid than the workpiece. For the example considered, Fig. 5 shows a maximum sag of 0·008 mm of the foundation over a length of 3·00 m, which is slightly below the permissible figure of 0·012 mm.

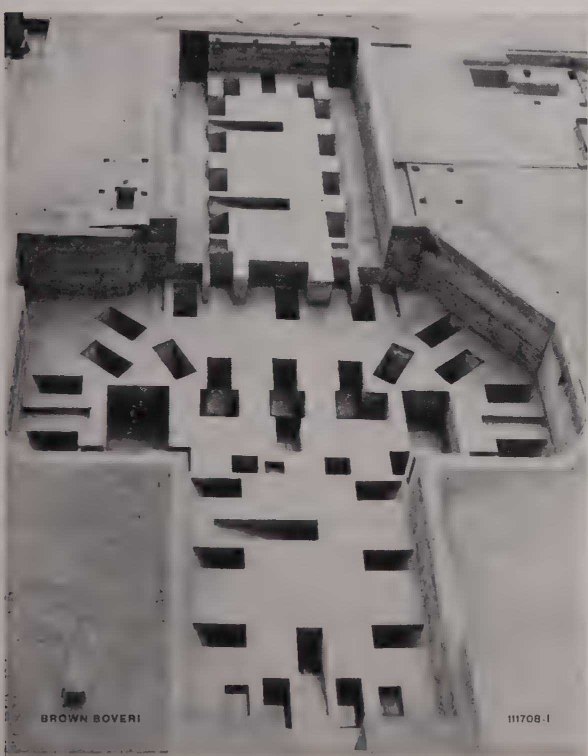


Fig. 4. – Foundations for a large milling machine

Bird's-eye view. The recesses are for the anchors beneath the base-plate and bed.

Transverse sag of the foundation

Here the problem was to keep the difference in sag y during the passage of a workpiece through the gantry as small as possible (Fig. 6). In the example considered, the calculation yielded values for Δy of the order of only 0·001 mm, which can therefore be ignored.

Local penetration of the concrete by the supports (wedges)

In addition to the sag of the foundations, the supports penetrate the concrete at each point of attachment of the base-plate, by an amount proportional to the pressure exerted at these points. These penetrations can be calculated from Timoshenko's theory of

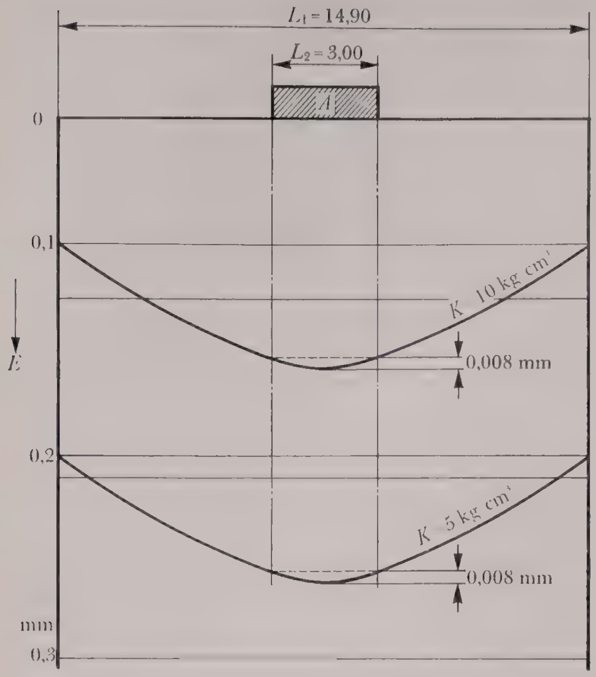


Fig. 5. – Settlement and sag of the foundation for different values of the modulus of reaction K, caused by a workpiece A (weighing 58 t) at the mid-point of the foundations

E = Settlement
L_1 = Length of foundation
L_2 = Length of workpiece

elasticity.[4] In the position I, i.e. when machining commences (Fig. 3), the workpiece imposes a load on the 14 supports below the right-hand portion of the bed, the most unfavourable condition being assumed to be when the base-plate and gantry remain unaffected by this load. The 14 supports sink a distance y, relative to the gantry. During machining, the workpiece advances through the gantry; in position II it loads the 25 supports beneath the base-plate, the right-hand part being assumed to be relieved in this state. In position II, however, the workpiece, gantry and base-plate all sink by the same amount. Consequently between I and II there is a difference of y_1 between the heights of the workpiece relative to the gantry. Thus, if the milling cutter starts at a definite height on the workpiece in position I, it will shift downwards relative to the workpiece in the course of the machining process, by y_1 in position II. This value y_1 therefore has to be taken into account as one of the factors affecting the accuracy of machining. In the case in point it amounts to 0·006 mm.

[4] S. TIMOSHENKO: Theory of Elasticity, New York 1936.

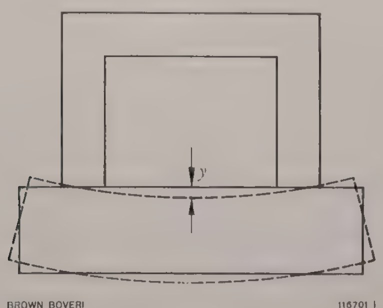


Fig. 6. – Transverse sag y of the foundation

Compression of the wedges

The effect of this compression is the same as the penetration of the concrete. All considerations discussed in the foregoing paragraph can be applied here accordingly. To determine the extent of the compression under particular loading conditions thorough investigations were undertaken several years ago, from which the value of y_1 in the present case works out to 0·014 mm.

Elastic deformation of the base-plate, bed and table

These will not exert any influence in the case in point because they may be treated as constant throughout the entire motion of the workpiece. They are, of course, always present in every position of the workpiece, but owing to the unchanging load are equal all the time.

Thus we arrive at the following state of affairs: While the sag of the foundation has no effect on the machining accuracy if a sufficiently rigid design is adopted, the only remaining effects are the compression of the supports and their elastic penetration into the concrete. The sum of these effects in the present example is $0{\cdot}014 + 0{\cdot}006 = 0{\cdot}020$ mm, which is precisely the tolerance stipulated for the machining accuracy.

Constructing the Foundations

The outlines of the foundations were in most cases governed by the data of the machines; whereas the depth was determined by the rigidity required. Since

only monolithic foundations were taken into consideration, the volume of concrete needed for these large machines was quite considerable. For the largest foundation about 1700 m³ were used. Obviously this amount of concrete had to be poured and treated in several stages.

The main dangers threatening the foundations were the shrinkage of the concrete, the development of unduly high temperatures during the curing process, and the poor cohesion in the joints between the different batches of concrete. These dangers had to be allowed for, on the one hand in the proportioning of the concrete, and on the other by careful mixing and curing. The material used was a vibrated concrete (P 300) with a compressive strength of over 300 kg/cm². The addition of a plasticizer allowed the amount of water to be considerably reduced, thereby increasing the strength and lessening the shrinkage. For pouring the concrete the pumping system installed proved ideal, as indeed it did for all other parts of the building.

To counteract the effect of excessive heat generation concrete was poured in fairly thin horizontal layers and allowed to cool for at least two weeks before continuing the pouring. A further measure to counteract shrinkage was to cover the entire upper surface with water, while thoroughly roughening the surface together with the reinforcement assured the necessary cohesion between the successive layers. In addition to the steel content determined by the static calculation, reinforcing bars were laid crosswise along all outer surfaces in order to avoid the risk of cracks, as far as possible. The complete separation of the machine foundations from all other parts of the building is intended to prevent the transmission of vibration.

Grouting the Machine Base-Plates

Many and varied were the problems which had to be faced when grouting in the base-plates of the machines. These are often large interconnected pieces of cast steel, fitted with anchors, for which the necessary recesses have to be provided in the foundations (Fig. 7). The design of the supports was such that the anchors could only be grouted in beforehand in a very small number of cases, since small lateral deviations by the grouted anchors were not within the building tolerances and could not be corrected subsequently. On the other hand, after the anchors had been grouted in, the surface of the foundations had to be coated with an oil-resistant paint, which would not have been possible after positioning the base-plate. The procedure adopted was that the base-plate with all anchors was placed in position and accurately adjusted. Then the anchors were grouted in and the base-plate, which until then had acted as a template, was lifted off again. The surface could then be cleaned and painted before the base-plate was finally fastened down.

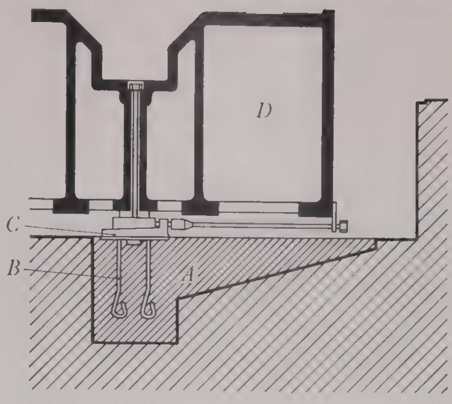


Fig. 7. – Support for the base-plate

A = Recess in foundation, grouted after the anchors have been positioned
B = Anchor
C = Adjustable support
D = Base-plate

From the remarks in this article it will be apparent that the investigations described had to deal with extremely small deformations of the workpieces and machines involved. Measurements carried out since on workpieces machined on these new foundations, prove that the accuracy obtained complies fully with present-day requirements.

(KME) R. Zimmerli

The 42 m high concrete tower of the boiler-house approaching completion. On the left the steelwork of the factory building


KAMPF

General view of the first phase of the building, with the largest assembly shop in the foreground. It is 270 m long, 36 m wide and 32 m high. The steelwork is covered by 15 roof bays, of which two are seen finished. Parallel to this main workshop are two smaller ones 24 and 18 m wide

Looking north at the factory in an advanced stage of erection. The three bays already have their roof in position and the boiler-house (right) is completed. For the first phase it contains two large boilers producing 12 tons of steam per hour, which is utilized for heating. A third, smaller boiler with an output of 6 t/h is used for the shrinkage process in the assembly of machines

View of the three workshop bays, each 270 m long, with their saw-tooth roof, at the end of the preliminary building work. The roof-lights, which face north, provide excellent daylight illumination in the workshops

The new factory, seen from the north-east, is rapidly approaching completion. In the foreground is the largest workshop bay 270 m long, 36 m wide and 32 m high. In the background is the boiler-house

Modern cranes in the middle workshop (24 m wide) at Birr. In addition to the 10-t travelling-bracket crane with an arm extension of 10 m, in the foreground, there are five overhead travelling cranes with capacities of 60 and 40 t, powered by Ward-Leonard drives for the hoists, in some cases also for the beam and trolley drives

AUXILIARY SERVICES

The distribution systems, the electrical system, lighting in the workshops, and the cranes are all auxiliary services which have to perform special tasks in a modern factory. An interesting design was evolved for the passages in which the various distribution systems are run. The article also describes the system providing the power for the machine tools, the facilities for testing the finished machines, as well as the lighting scheme and the cranes. The latter are described in detail in the final chapter, with particular reference to their employment for lifting and carrying.

IN 1956 the Company's own Installation Department was set the task of supplying electricity, water, heat, compressed air and gas to a large new factory in the Birrfeld area which, until then, had been untouched by industry. The chapters which follow, in addition to providing a technical summary of basic methods, also describe some quite new and interesting details of the following auxiliary services:

Distribution system
Electrical installation
Lighting
Cranes

DISTRIBUTION SYSTEM

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The distribution of the different kinds of energy, and commodities needed within the factory, from central generating and supply points to the last consumption point, presented problems regarding the layout of cabling and piping, which had to be solved in collaboration with the building specialists. To retain flexibility in the event of rearrangements becoming necessary, to provide generous reserves for future extension, to render the pipes and cables accessible at all points and to ensure a systematic layout in the interest of reliability and prevention of accidents and, by no means least, to conform to the aesthetic requirements, were the main factors which had to be taken into consideration when planning the installation.

In the new Birr works all electric cables and sanitary pipes are laid in passages through which a man can walk, or in covered floor ducts. Apart from the few supply leads for the overhead space heaters, the air-lines for pneumatic operation of the roof-lights, and the wiring for the lighting, which are all concealed in the stanchions, the workshop bays are completely free of visible pipes or conduits, and consequently much neater and more uniform in appearance.

The foundations of the outer row of stanchions are hollow, thus providing a passage 300 m long, which acts as the main longitudinal artery of the whole factory (Fig. 1). Connecting and transverse passages of equal dimensions link the factory with the detached boiler-house and the main substation. Together with the underground factory facilities, the distribution boards and central-heating station, the rooms in which the converters for the large machine tools are centrally installed, the cross-bar selectors and switchgear for the test-

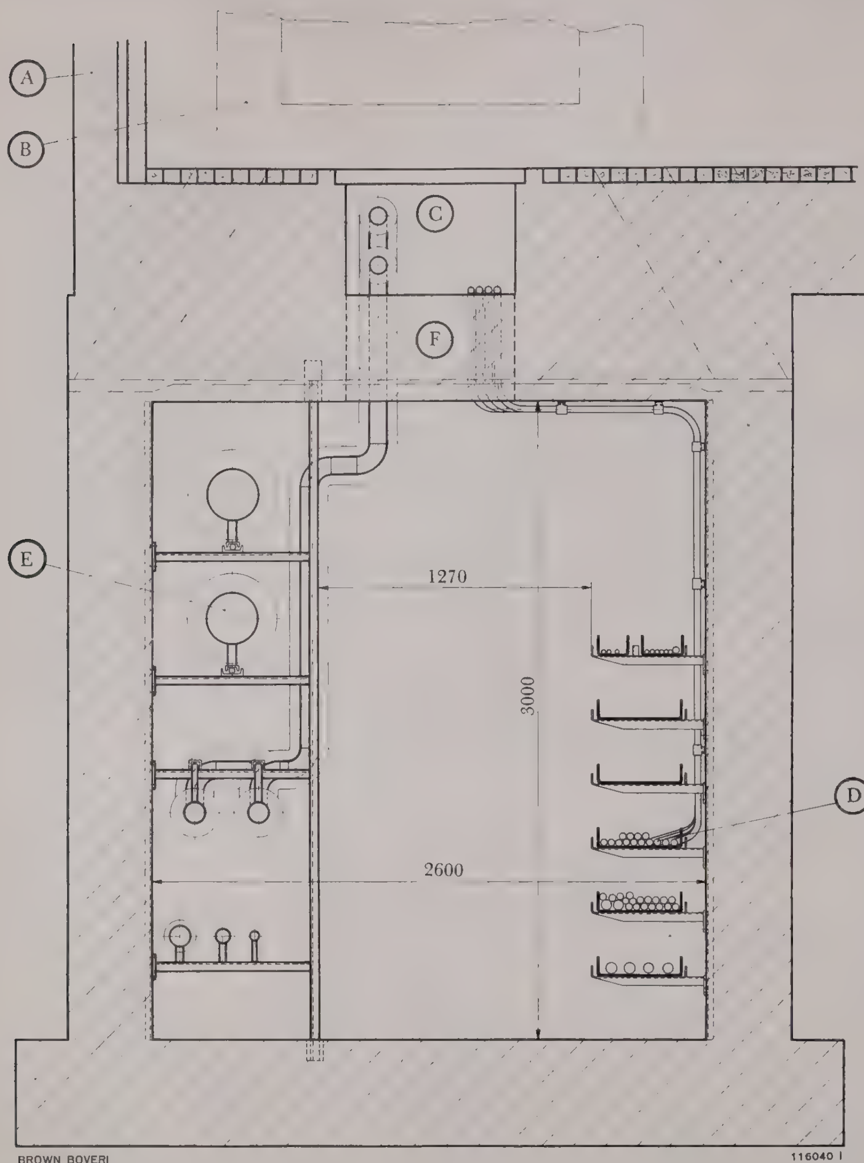

Fig. 1. – Section through a service passage formed by the box-shaped foundations of the main stanchions of the 36-m bay

A = Outer wall
B = Stanchion
C = Covered floor duct in the workshop
D = Electric cables in asbestos cement trays
E = Pipes for heating, compressed air, and gas
F = Entry into the floor duct

beds, the pumps and reservoirs for the supply of oil under pressure and cooling water, the plant for neutralizing certain waste water, and ventilation system, they form a self-contained operations centre (Fig. 2). As soon as new, detached groups of buildings are erected, the co-ordinated system of passages will be extended accordingly, the neccessary connection points having already been allowed for in the overall conception.

The arrangement of pipes and cable at one of the junctions in the passage, owing to the difficulty of drawing them out on paper, were represented by a three-dimensional model to a scale of 1 : 10 (Fig. 3). Despite the fact that the relativity high-level drainage system made it impossible for these awkward junctions to be designed on two levels, a solution was found which allows the bundles of electric cables and pipes to be run systematically without complicated diversions and crossings, by allocating each one wall or the ceiling of the passage.

A compact network of Jordal bars combined with clamped brackets and holders allows the cable or piping system to be rearranged or extended at any time, without any need for chiselling or welding.

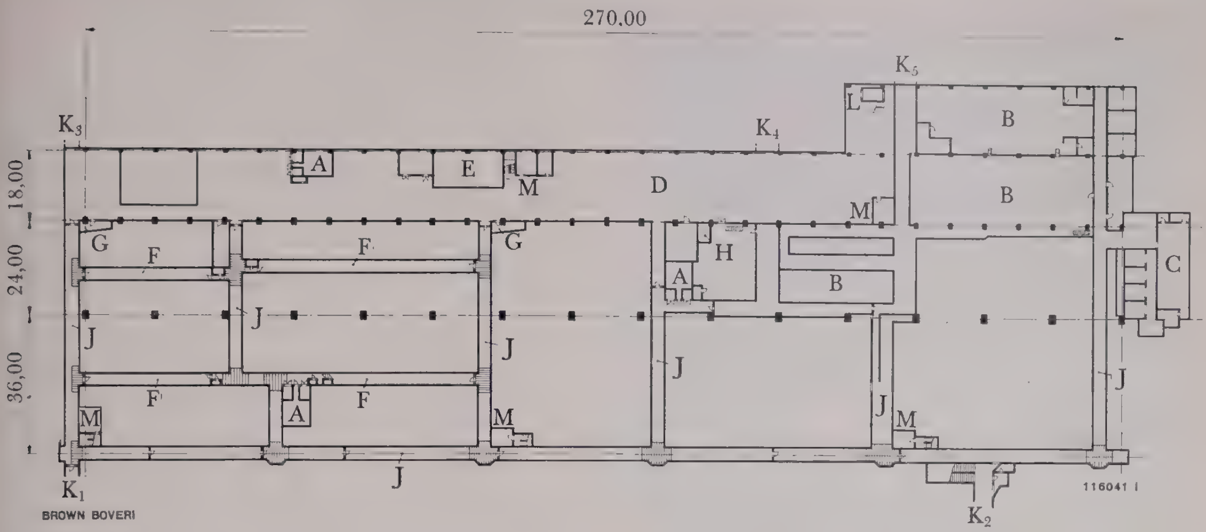

Fig. 2. – Plan of the service passages and underground facilities

A = Distribution boards 8000/380 V
B = Cross-bar selector and other test-bed equipment
C = Basement of main substation 45/8 kV, with diesel set in the event of a power failure
D = Storage cellar, auxiliaries for winding shop
E = Heating substation, neutralizing plant
F = Converters for the machine-tool drives
G = Ventilation compartments
H = Central supply point for acetylene and oxygen
J = Service passages exclusive to workshops
K_1 = Passage to boiler-house
K_2 = Passage to cloakroom and canteen
$K_{3,\,4,\,5}$ = Connections for future buildings
L = Goods lift
M = Sanitary facilities
Dimensions in metres

In the distribution passages, pipes for inflammable gases and oxygen run adjacent to h.v. power cables. To prevent dangerous concentrations of gas, caused by leakage at the pipe fittings, or the emergence of sewer-gas, the passages are artificially ventilated. To prevent flames or smoke from being spread in the event of a fire, and to stop the supply of oxygen in such cases, this ventilation system can be shut

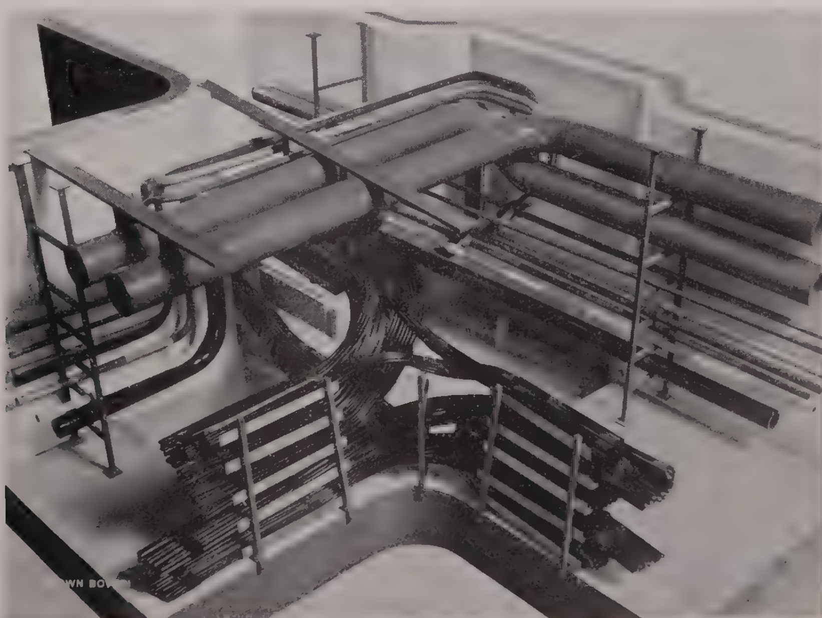

Fig. 3. – Model showing a junction point to illustrate the layout of cabling and piping (scale 1 : 10)

Fig. 4. – Cable branch point in the basement

off from one point, should the need arise. Fireproof partitions with fire-prevention doors divide the system of passage into separate underground sections.

In the workshops a network of floor ducts was provided, normally covered with wooden blocks. According to the type of work performed in the bay, this network is made close (small machine section), broad (assembly area and despatch), or adapted to the positions of the machine tools. These floor ducts of different cross-sections are directly connected with the passages and conduct the secondary cables or side-lines of the drainage system to the distribution points in the bays, and finally to the machines themselves. The leads to the machines can be quite easily run in the floor beneath the wood-block covering, without harming the concrete.

(KME) H. R. RÜEGGER

THE MAIN ELECTRIC SUBSTATION

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The need for a clear, simple layout offering maximum reliability and safety with an appreciable reserve capacity is reflected in the electrical installation of Birr works.

The focal point of the whole installation is the main substation, which is already designed for the capacity needed when the works are extended, and is situated at the north end of the 24-m bay. The entire demand is catered for by the system of the Aargauisches Elektrizitätswerk, from which power is supplied at an input voltage of 45 kV. The power consumed is measured at the input voltage, stepped down to 8 kV, and for reasons connected with operational reserves and tariff rates, fed at this voltage into two networks, each with their own distribution boards, supplying the factory and test station.

Connected to the first of these networks, which may be referred to as the factory network, are all load circuits concerned with production and auxiliary services. The other, or test network supplies all the energy required for tests on finished machines or for development work; a characteristic feature of this network is the high load peaks and surges with a relatively low total power consumption.

The basic layout of the substation is seen in the circuit diagram (Fig. 1) and the sectional elevation (Fig. 2), showing the division into the following sections:

45-kV section, with intake, power-metering equipment, main switchgear and the step-down transformers;

8-kV section, with switchgear and distribution board for division into the "factory" and "test" networks controlling the feeders to the 8000/380-V distribution boards situated at various points in the building. It also contains a control room with

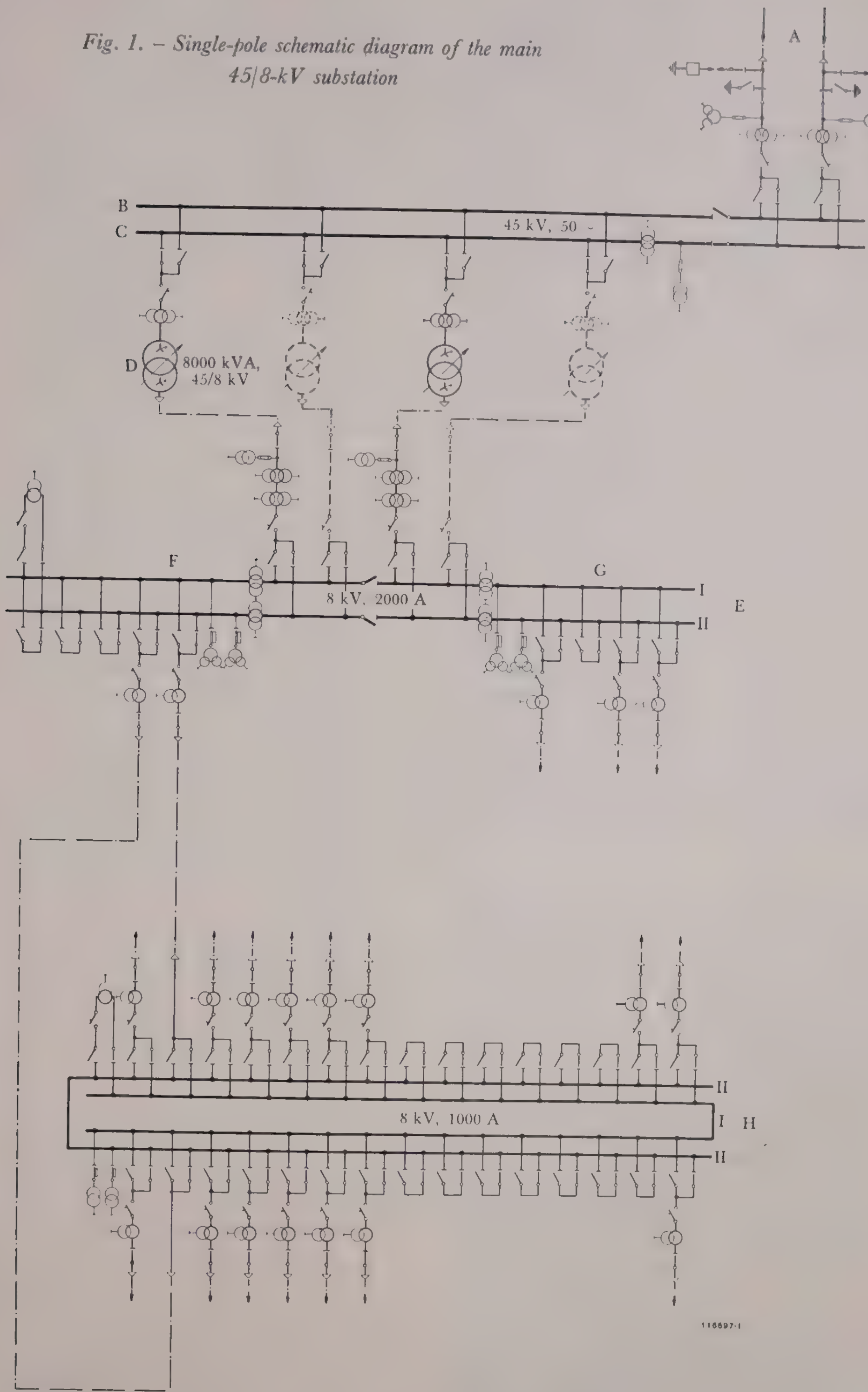
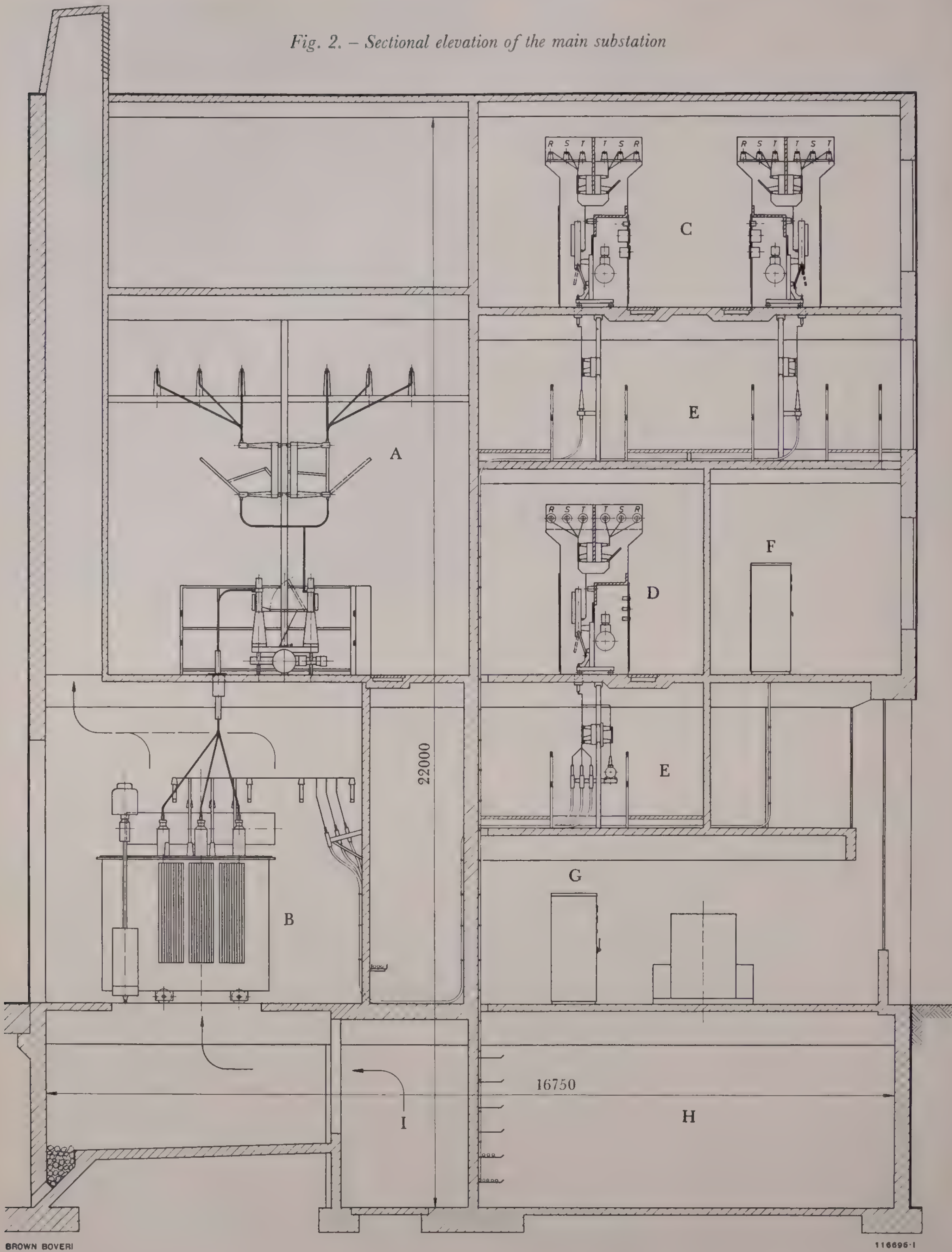


Fig. 1. – Single-pole schematic diagram of the main 45/8-kV substation

A = Incoming 45-kV cable, with instrument transformers for line protection
B = Auxiliary busbars
C = Metering busbars (for input energy)
D = Main transformers (dotted—future extension)
E = Main distribution, duplicate busbars I and II, 8 kV, 2000 A
F = 8-kV busbar system with feeders to factory distribution network
G = 8-kV busbar system with feeders to testing station
H = Factory distribution board, feeding the local distribution boards

Fig. 2. – Sectional elevation of the main substation



A = 45-kV switchgear
B = Tap-changing transformer 8000 kVA, 45/8 kV
C = Factory distribution board 8 kV
D = Main 8-kV distribution board
E = Cable room
F = Control room
G = Station auxiliaries 380/220 V
H = Cable basement
I = Ventilation duct

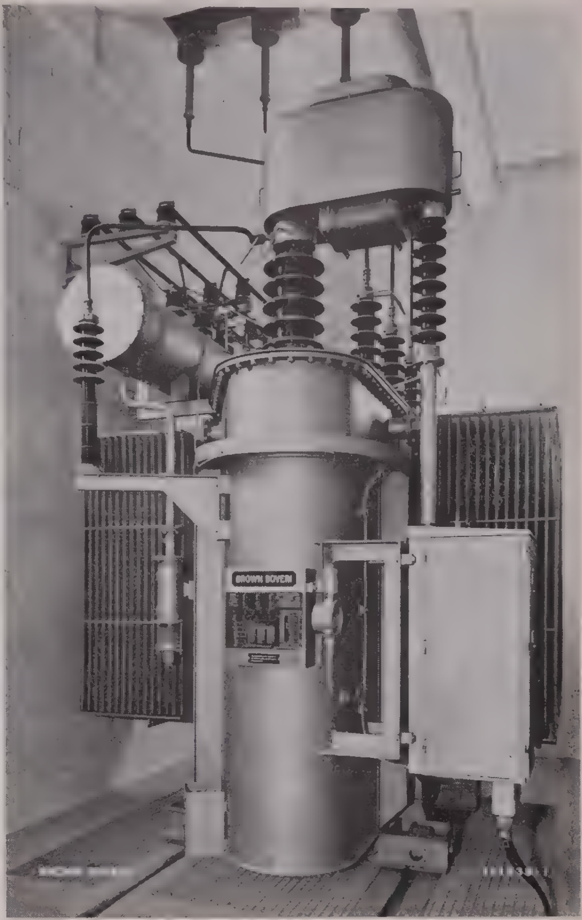


Fig. 3. – Naturally cooled tap-changing transformer rated 8000 kVA, 45/8 kV

metering, control and protective equipment, with auxiliaries including an 8000/380-V distribution board, batteries for control circuits, the air compressors and an emergency diesel-generator set.

The 45-kV Section

The two-storey 45-kV section is of the conventional open type and equipped exclusively with oilless switchgear of the 60-kV series.

At ground-floor level are the incoming 45-kV cables from the Aargauisches Elektrizitätswerk, with their lightning arresters and isolators, and the current and voltage transformers for line protection. These instrument transformers simultaneously act as the bushings between the two storeys.

Also on the ground floor, installed in separate cells are the two tap-changing transformers (later to be increased to four) rated 8000 kVA each, 45/8 kV (Fig. 3). For repair or inspection the transformer can be run straight out into the adjoining workshop under a crane. Should the factory demand increase beyond this capacity in the distant future, it is possible for these transformers to be replaced by 12 000-kVA units, thus raising the total capacity to 48 MVA. Each transformer is designed for automatic tap-changer control in 23 steps, controlled by an impulse regulator on the 8-kV side. The transformers can be connected singly or jointly with any desired grouping to the 8-kV busbars, thus allowing the transformer output to be matched to the momentary demand of the factory and testing station.

In the upper storey the busbar system is equipped with isolating switches and airblast circuit-breakers having a breaking capacity of 1500 MVA (Fig. 4) and, to enhance the reliability, with auxiliary and

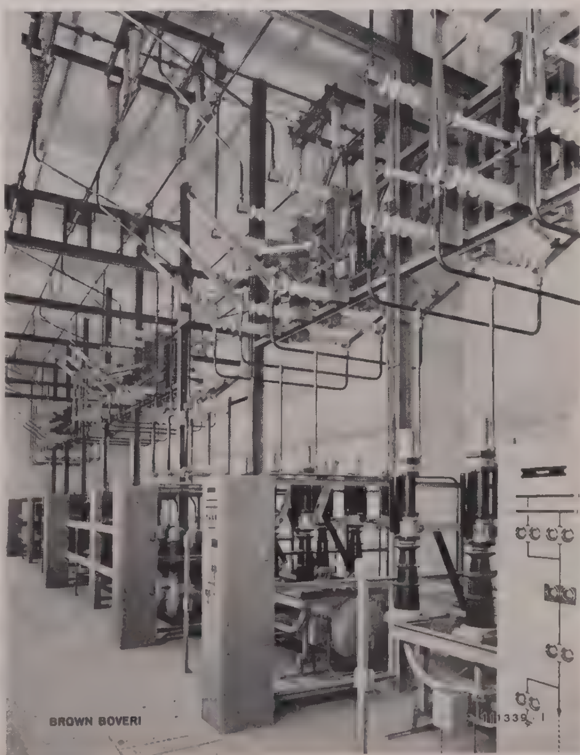


Fig. 4. – Open-type 45-kV switchgear with 60-kV airblast circuit-breakers having a rated breaking capacity of 1500 MVA

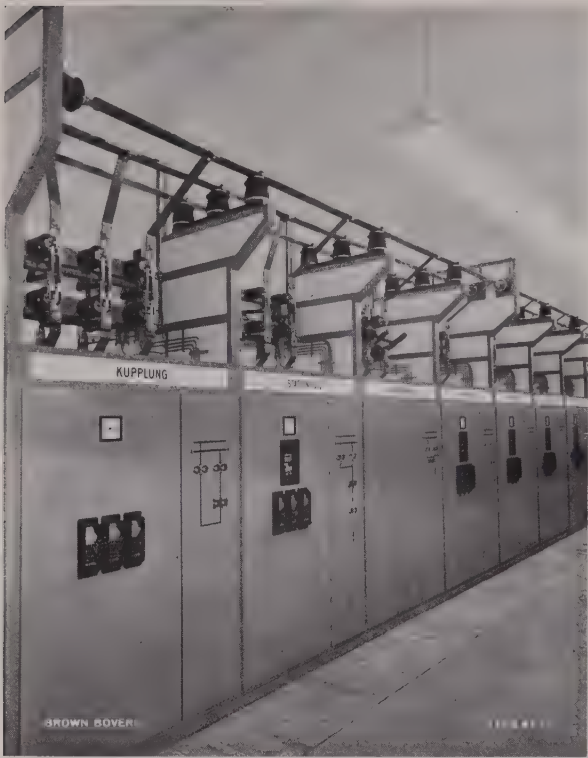


Fig. 5. – Some of the 8-kV cells with metering, protective and control equipment

metering busbars. This floor also contains the equipment for totalling the power consumed.

The pneumatically operated isolators, with indicator unit, are electro-pneumatically interlocked with the circuit-breakers.

For the control of each cell there is a cabinet containing all the devices needed for direct and remote control. Their operation is greatly simplified by incorporating the various push-buttons in a mimic diagram on the front of each cabinet. Installation and overhauls can be carried out safely at any time because the steelwork is arranged for the insertion of insulating barriers.

The 8-kV Section

The main distribution gear on the first and second floors has to perform the following duties:

Switching the transformer secondaries in any desired grouping;

Dividing the energy between the "factory" and "test" networks;

Feeding the load circuits in the testing station and the 8-kV factory distribution board in the main substation.

In an emergency the divided busbar systems of the factory and test networks can be combined by coupling the longitudinal busbars. To improve the safety of the power supply duplicate busbars are provided, a transfer breaker ensuring that a changeover from one bus to the other is made without interrupting the supply. The busbars are designed for a service current of 2000 A, and since more than three transformers will never be connected in parallel, the maximum peak value of the short-circuit current for the busbars is 95 kA.

All switchgear is designed for a rated voltage of 10 kV; at 8 kV the airblast circuit-breakers have a rated breaking capacity of 600 MVA and can handle a peak short-circuit current of 120 kA.

The machines of the testing station are connected to a pair of feeders, one of which is always in reserve, a safety precaution which was also taken for the supply to the l.v. distribution boards.

8-kV Factory Distribution

From the main distribution gear on the second floor of the substation, the 8-kV factory distribution gear on the third and fourth floor is fed via two (later to be three) single-conductor paper-insulated cables having a cross-section of 300 mm^2. The large number of spare cells which are at present unequipped clearly shows the extent to which the factory is expected to expand.

The duplicate busbar system is designed for a rated current of 1000 A. All the airblast breakers in the feeders to the factory distribution boards can be remote controlled from these boards by a system of light-current control.

To protect the 8-kV gear against short circuits and to afford maximum safety to maintenance staff, the duplicate busbars, busbar isolators and breakers are enclosed in an angle-iron framework with plaster walls. The two busbar systems with their respective isolators are separated from one another by a longi-

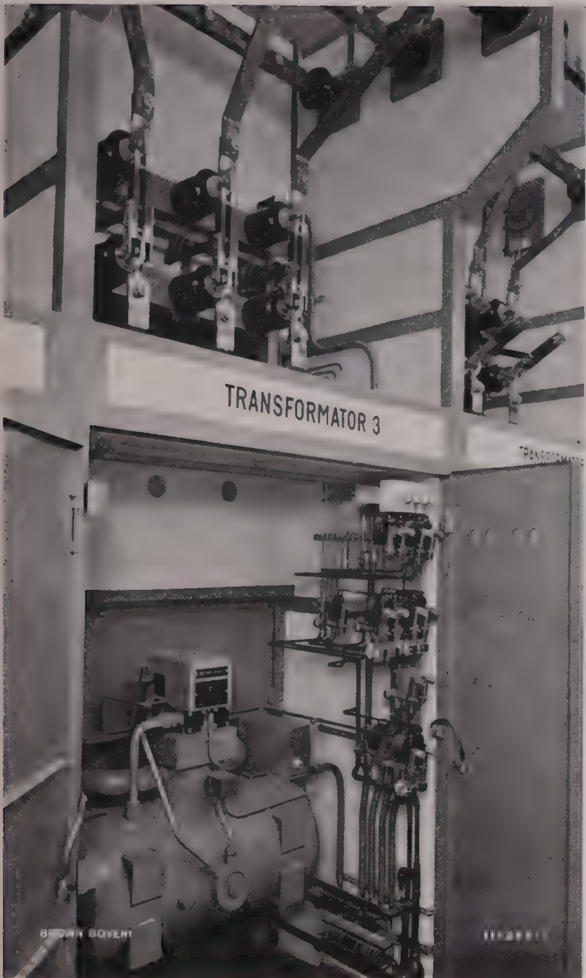


Fig. 6. – Low-voltage recess of an 8-kV cell, with doors open

Separated from the h.v. side by a vertical metal plate is the air receiver of the circuit-breaker; adjacent to it are the pneumatic valves and push-buttons for operating the isolators and circuit-breakers.

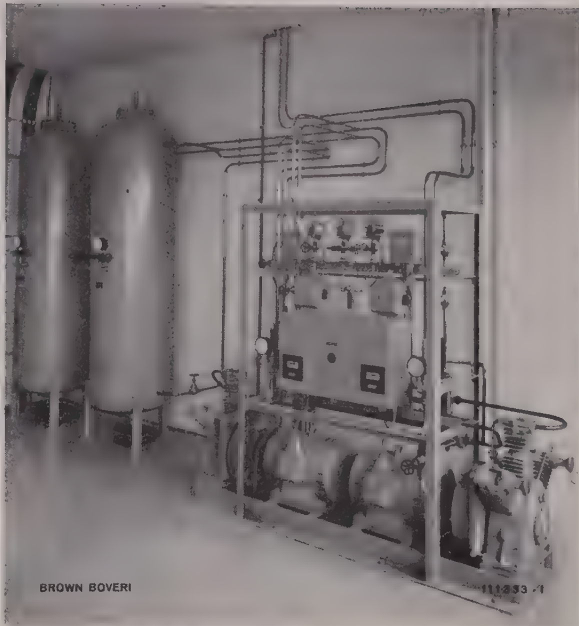


Fig. 7. – Unit-type air compression plant with receivers

tudinal barrier. At intervals of three to four cells, transverse barriers are provided, with wall bushings, to prevent possible arcs from migrating along the busbars (Fig. 5).

At the front of each high-voltage cell is a low-voltage recess of plasterboard, closed by double metal doors. It contains all metering, protective, control and auxiliary devices, the control elements being mounted on the door in the form of a mimic diagram. From the circuit-breakers, which are on wheels, the air receiver, control block and indicator switch project into the recess (Fig. 6). The latter is separated from the h.v. side by means of a back-plate attached to the breaker, which allows the recess to be safely inspected at any time. All isolators are pneumatically operated and equipped with auxiliary signalling contacts; since the isolators and breakers of the factory network are seldom operated, it was possible to dispense with interlocking and remote control from the control room. But to prevent inadvertent operation of the isolators on-load, the isolator control valves in the l.v. recess, with their push-buttons, are covered by a hinged transparent plastic hood. When the leads disconnected the switch can easily be withdrawn into the maintenance gangway at the rear, without the bushing-type current transformers having to be dismantled.

Control Room

This is situated on the second floor and accommodates the switchboard, which is divided into three sections. The right-hand section contains the 45-kV metering and protective gear, the associated control switches with mimic diagram, also the Printomaxigraph recorder which registers the total amount of power drawn. In the middle section are the metering and recording instruments for measuring the electri-

city consumed by the factory and test networks on the 8-kV side. Part of this board contains all the gear for testing for earth leakage.

The left-hand section serves the main 8-kV distribution. In addition to the metering, control and protective gear with a mimic diagram, it contains the impulse regulators and accessories for automatic control of the transformer tap changers.

The incoming 45-kV lines are protected by high-speed distance relays, the 8-kV cables and transfer breakers with overcurrent-time relays. Each transformer is protected against overload by a thermal relay and against external short circuits by two secondary overcurrent relays. Internal defects in the 45/8-kV transformers are detected by three single-pole differential relays.

Auxiliaries

Compressed air is supplied by two air-cooled reciprocating compressors, each producing 15·5 m³/h at a pressure of 30 kg/cm². It is transferred to the switchgear through receivers and reducing valves at a service pressure of 15 kg/cm² (see Fig. 7). The same supply is utilized for the pneumatic isolators and airblast breakers in the testing station.

The auxiliary current for control purposes and alarms is provided by a lead-cell battery rated 144 Ah at 110 V, with a tapping at 48 V for the remote-control system,

An auxiliary transformer station on the ground floor, with an output of 2×1200 kVA at 380/220 V, 50 c/s, provides the supply for the lighting and the substation auxiliaries and maintenance building. Two automatically controlled diesel-generator sets, each rated 100 kW, 380/220 V, supply all the emergency services.

Installation was commenced in October 1958 and by the middle of May 1959 the main substation was ready for service.

(KME) F. TOGNOLA

POWER DISTRIBUTION IN THE FACTORY

621.316.176

General Principle

The schematic layout in Fig. 1 shows how the electricity for power, heating and lighting is conveyed from the main switchboard in the substation via 8-kV cables to the factory distribution centres (transformer units) which are situated close to the load centres in the various bays. After transformation down to 380 V the power is distributed to the individual consumers by short leads of heavy copper cross-section in which the voltage drop is low. If these consumers, e.g. large machine-tools, furnaces, welding plants, impose a load of more than 150 kW, they are connected direct to the transformer unit; for others the power is distributed through truck-type switchgear, from which machines rated over 50 kW are supplied direct, and the others from the numerous switch-fuse units and socket outlets mounted on the stanchions.

Should the whole supply system or individual parts of it fail, two emergency diesel sets, each rated 100 kW, automatically maintain the flow of power to essential circuits, e.g. the emergency lighting, the oil and cooling-water supply systems, and the socket outlets for repair work.

8000/380-V Distribution Centres

The distribution centres are of uniform design and only occupy an area of 9×6 m and, except for the unit feeding the cranes, are in the basement. The transformers and capacitors, which are the main

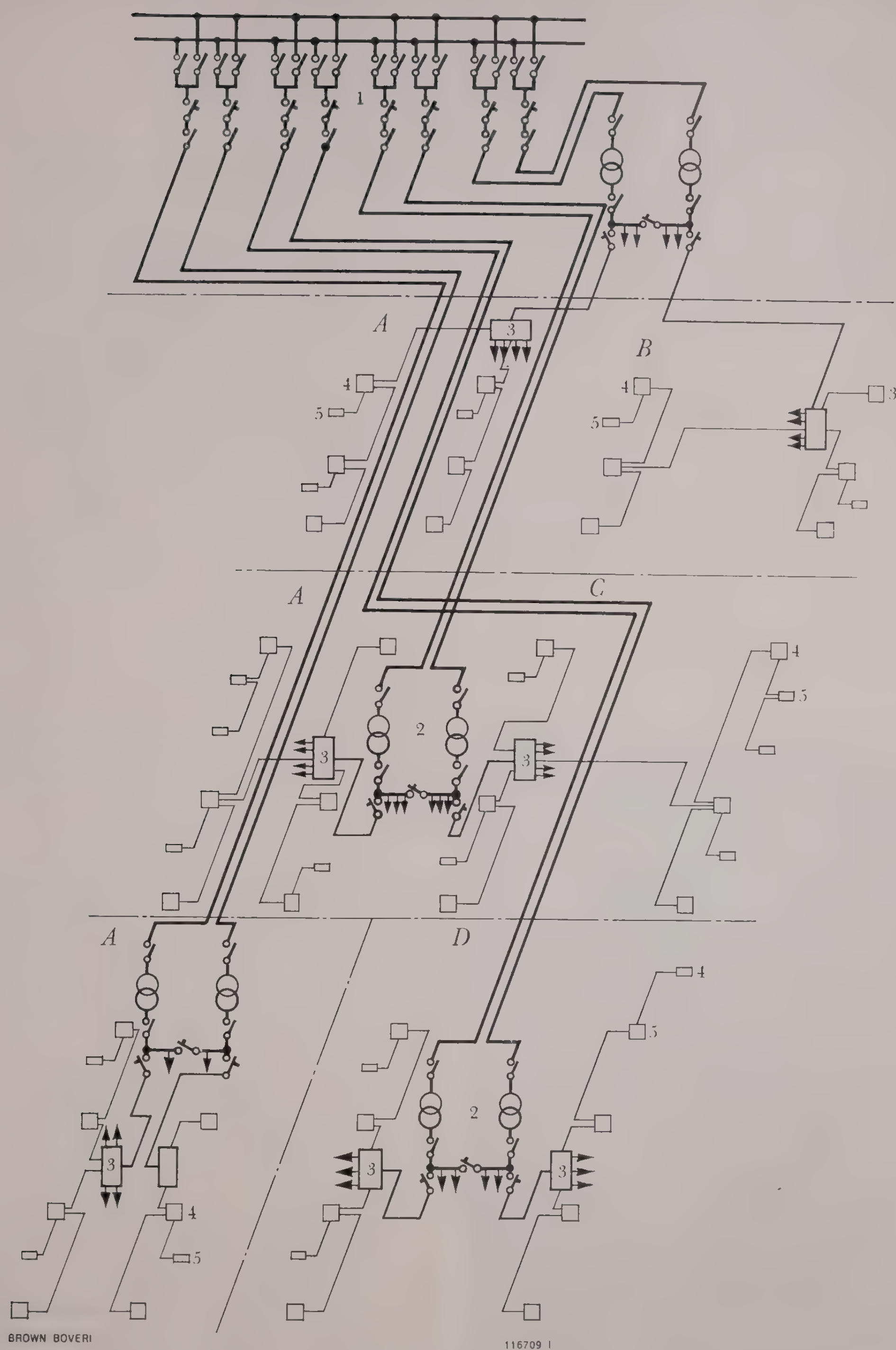


Fig. 1. – Schematic layout of the power distribution for the factory at Birr

This diagram shows how the power is distributed at 8 kV to the load centres, where it is transformed and conveyed to the various machines via metal-clad switchgear, switch-fuses and socket outlets.

1 = Factory main distribution gear 8 kV
2 = Distribution centre with transformer 8000/380/220 V, 50 c/s
3 = Metal-clad local distribution gear
4 = Switch-fuse
5 = Socket outlet

A = Winding sections
B = Despatch
C = Testing station
D = Section with large machine tools

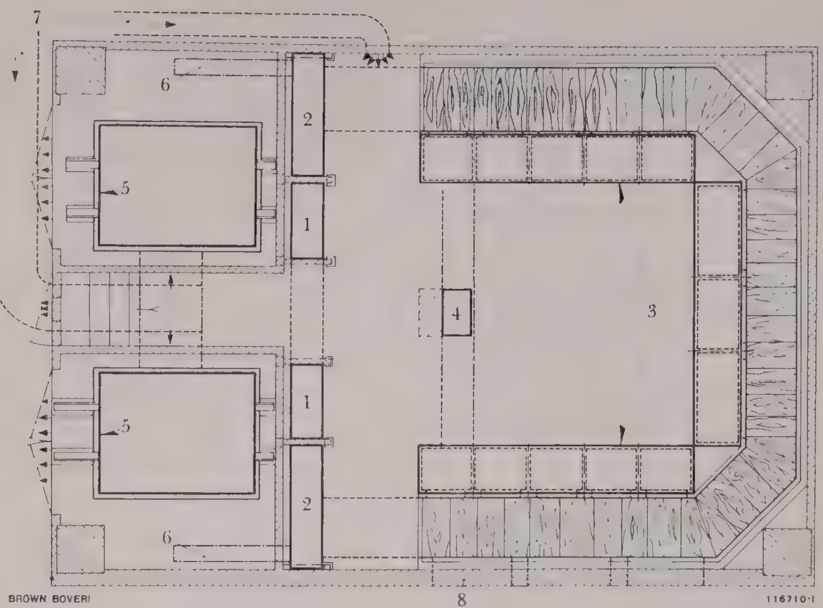


Fig. 2. – Plan of the standard distribution centre, showing the arrangement of the transformers and switchgear cells

This layout allows full advantage to be taken of a small amount of space.

1 = High-voltage incoming cell
2 = Power factor correction control
3 = Low-voltage feeder cells
4 = Control board
5 = Transformer
6 = Capacitor bank
7 = Ventilation
8 = Hole in wall for cable entry

sources of heat, are in artificially ventilated cells. The space for the operating personnel is completely isolated from the cells and receives its fresh air through a separate duct.

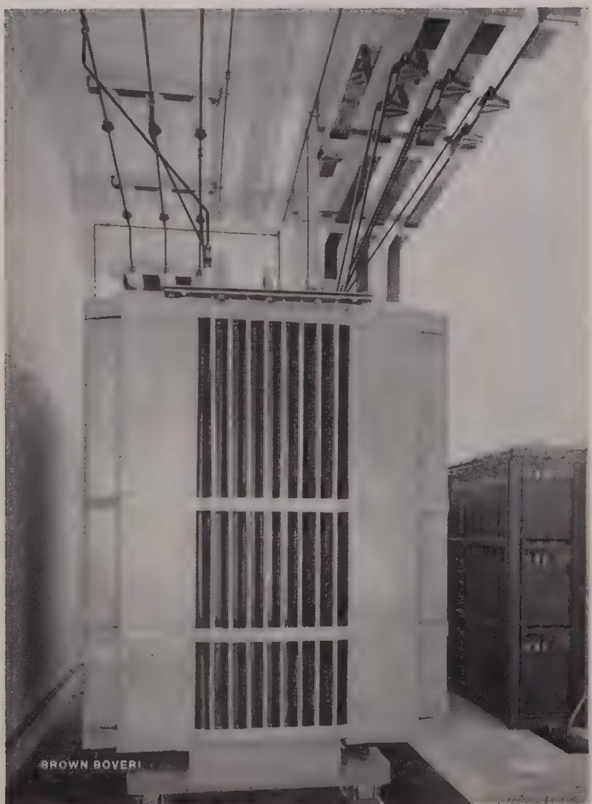


Fig. 3. – Transformer cell of a distribution centre

Housing the transformer and capacitor in one cell greatly simplifies ventilation.

The two 1250-kVA transformers (Fig. 3) are fed direct from the main factory distribution gear through unarmoured paper-insulated lead-covered cable with a thermoplastic sheath as protection against corrosion. In order to make these centres small and economical, a h.v. circuit-breaker was omitted. Instead, the corresponding breaker in the main distribution board can be operated from the centre by remote control with light current. An acknowledgement switch in conjunction with a miniature voltage indicator allows the position of the circuit-breaker to be determined with absolute reliability.

Connected to each transformer by busbars are five feeder cubicles rated 1000 A, equipped for power metering and isolated by air-break circuit-breakers (see Fig. 4 and 6), and eight groups of h.r.c. fuses rated 400 A, forming one-half of the outgoing cubicles in the centre. The two halves of the horseshoe are coupled by a breaker which permits a maximum balancing current of 1000 A in either direction. If the transfer current exceeds this figure, the breaker disconnects both systems. This action is particularly important in the event of a short circuit because, due to the graduation

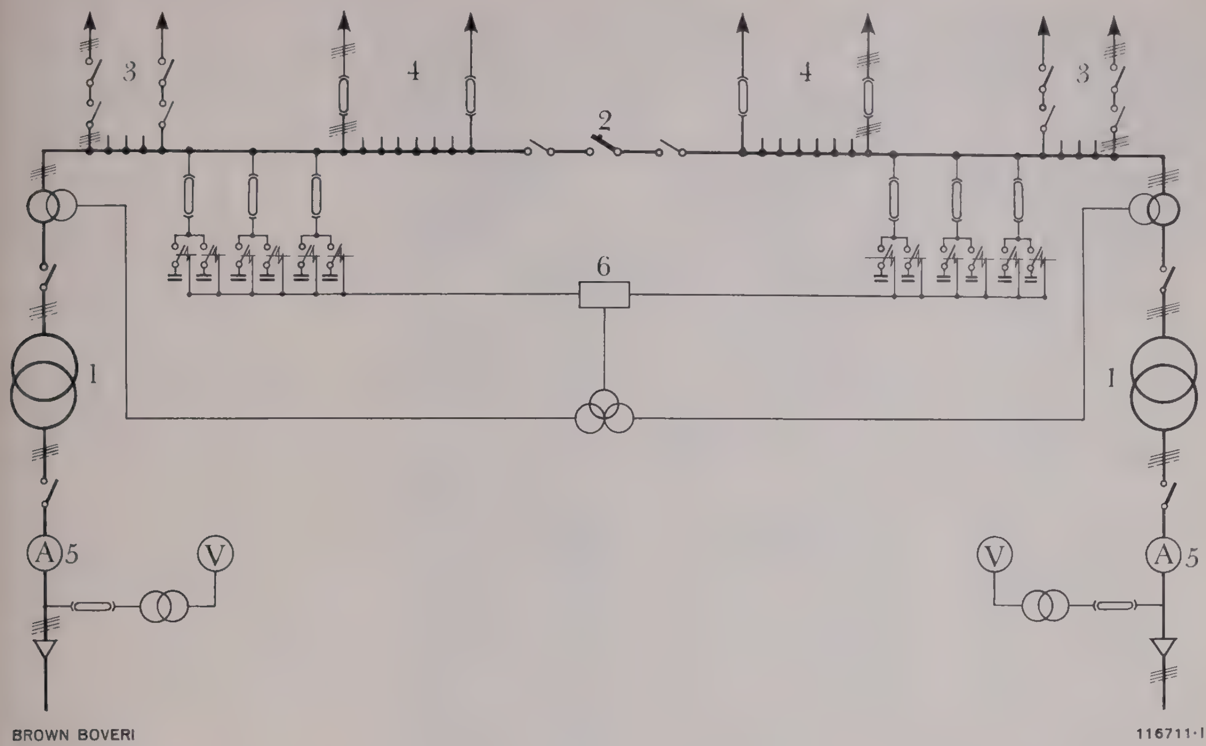


Fig. 4. – Circuit diagram of a distribution centre

In addition to showing the outgoing feeders with air-break circuit-breakers or h.r.c. fuses, the diagram depicts the symmetrical arrangement of the capacitors on each side of the transfer breaker. This prevents the latter from having to carry high capacitive currents which would cause the secondary relay to trip.

1 = Transformer 1250 kVA, 8000/380/220 V
2 = Transfer breaker 1000 A
3 = Feeder with air-break circuit-breaker, kWh-meter and secondary relays
4 = Feeder with h.r.c. fuse
5 = Busbar ammeter with maximum contact
6 = Reactive-power relay

of the relays' pick-up times, the amply dimensioned transfer breaker first reduces the short-circuit power, and later disconnects the affected part of the installation from the mains.

Correction of the power factor to 0·85 (later to 0·9) was stipulated by the power company. Thus capacitors having a rating of 960 kVar, divided into twelve banks, are provided for each complete transformer unit.

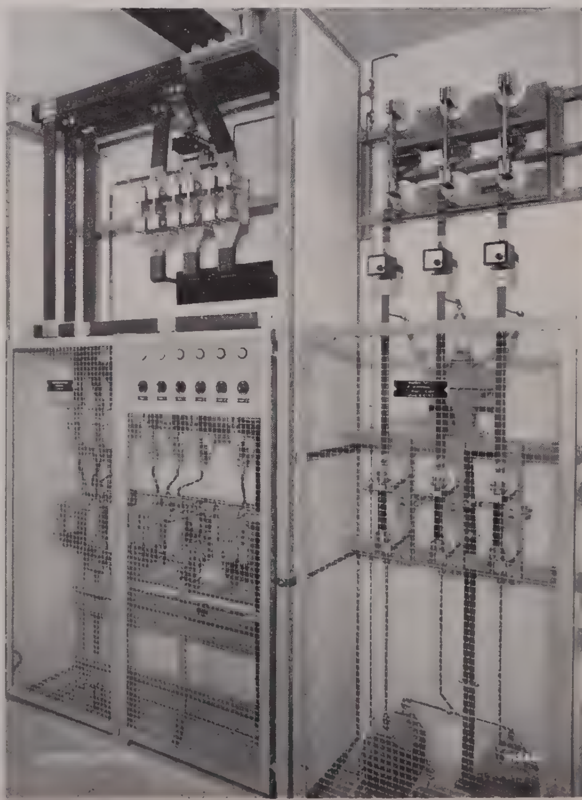


Fig. 5. – Input and control cells for power factor correction in a distribution centre

As shown in the plan view, the input and control cells for power correction are side by side. A clear demarcation between high and low voltage is afforded by a plaster barrier.

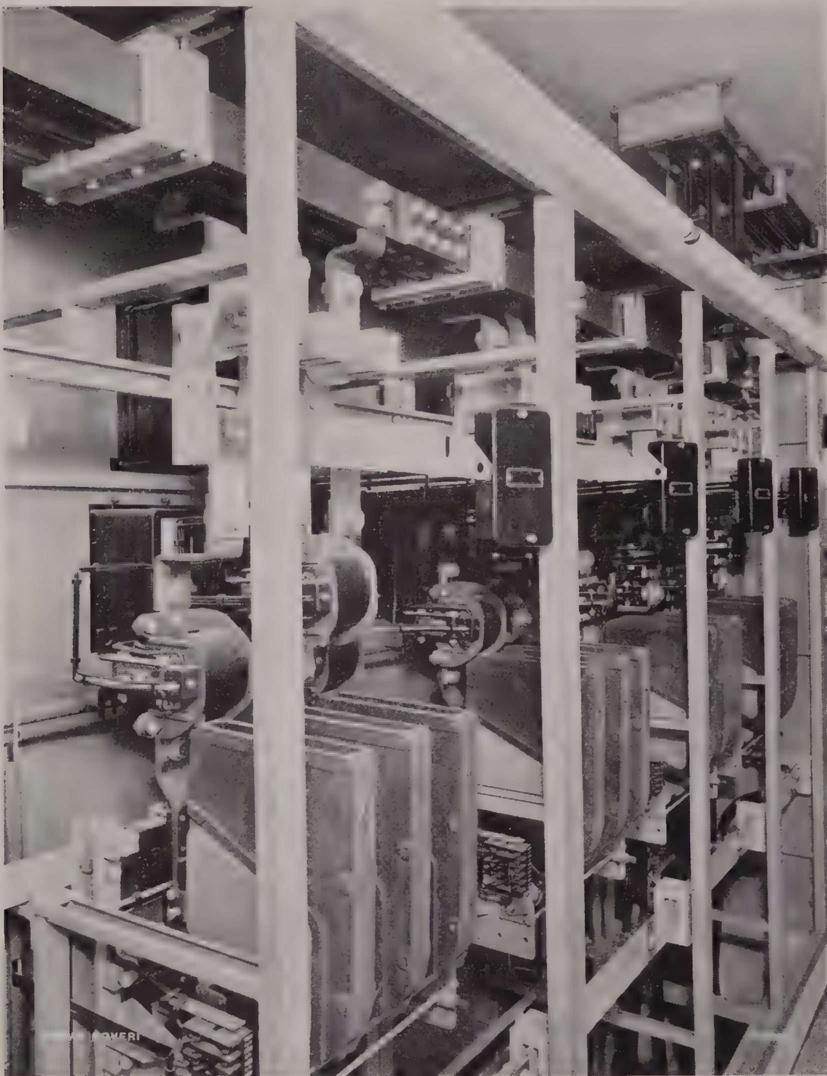


Fig. 6. – Rear view of the low-voltage gear in a distribution centre

The open rear part of the distribution gear is easily checked on the daily tour of inspection. In the event of a fault, all items of equipment and all connections are readily accessible.

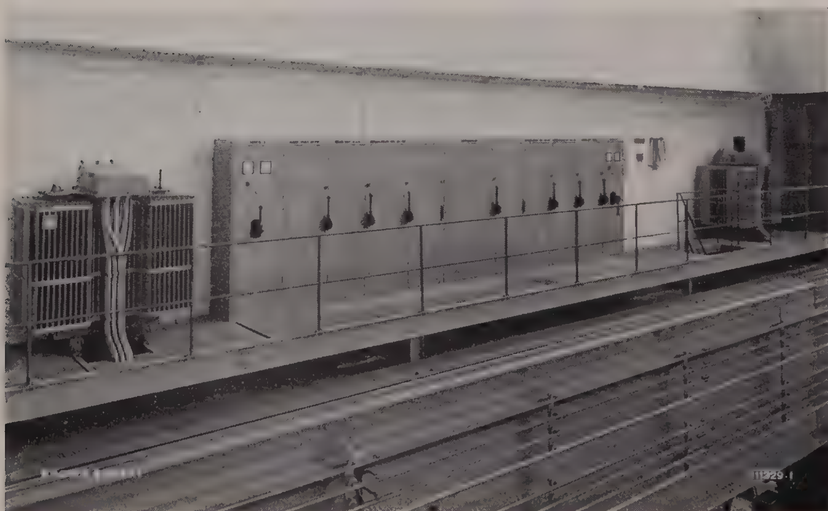


Fig. 7. – Crane distribution centre

By mounting the distribution gear for the cranes at the crane-rail level, it was possible to keep the leads to the contact wires very short. To afford maximum safety, the gear is all metal-clad.

The reactive power required is controlled in terms of the load by a relay which switches one bank of capacitors to or from alternate halves of the system, so that the transfer breaker does not have to carry the capacitive current. In these centres any number of capacitors can be switched on by hand as basic capacitive load. The switchgear for this is accommodated in a pair of cells (Fig. 5).

An entirely separate load centre is the point from which the contact wires for the overhead cranes are fed, where rated currents of up to 1000 A per contact wire are required. In order to keep the low-voltage leads to the two most heavily loaded contact wires as short as possible, a transformer centre with metal-clad switchgear is mounted at crane-rail level between the 36 and 24 m bays. This centre corresponds to the others, but is adapted to the special conditions of the point of installation, as shown in Fig. 7 and 8.

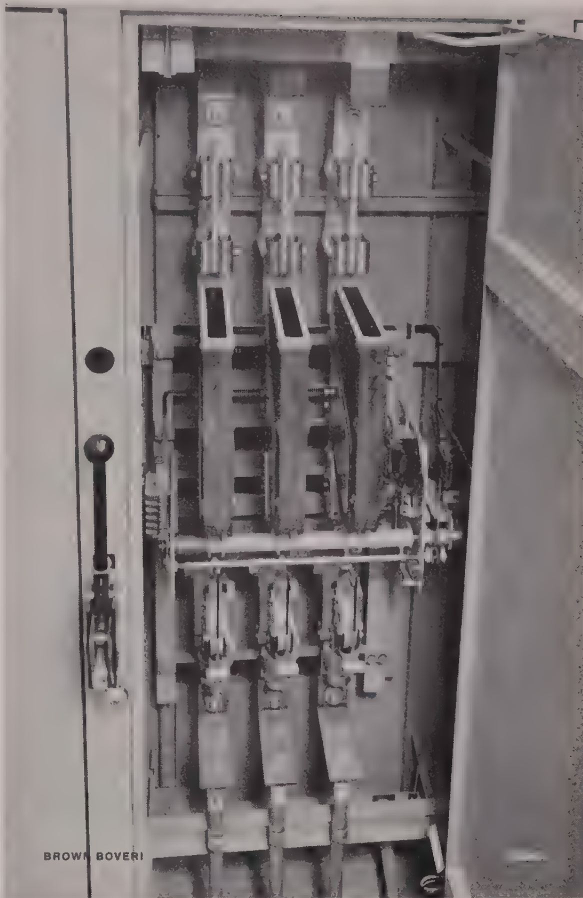


Fig. 8. – Detail of the crane distribution gear

In spite of the confined space, an ideal layout has been achieved by expedient arrangement.

Local Distribution Gear

From the distribution centres the l.v. cables run in asbestos cement trays through the underground passages, leave these through vertical openings and continue in the covered floor ducts to the local distribution point, with its metal-clad drawout low-voltage gear. The schematic diagram of a unit of this kind is shown in Fig. 9.

Three air-break circuit-breakers control the three feeders to the particular workshop, which are augmented by a close network of switch-fuses and socket outlets, the lowest order of distribution points, for loads of less than 50 kW. Four h.r.c. fuses are simultaneously isolators and protection for the direct leads to the consumers. One of these local units is shown in Fig. 10. When the breaker is withdrawn, inspection or overhauls can be performed in complete safety, since all terminals are isolated. If a breaker has to be replaced by a spare unit, there is no need to disconnect the main feeder, nor any of the other outgoing leads.

Central Installation of Converters

In order to simplify maintenance, to protect them against dirt, and to assure perfect cooling, the converters for the Ward-Leonard drives of the large machine tools are mounted in separate rooms in the basement. These rooms almost automatically had to occupy the space between the enormous foundations of the machine tools and are incorporated in the cable network.

An example, in Fig. 11, shows the numerous converters belonging to the large 14 m vertical lathe, supplied by Schiess of Dusseldorf. Each of these machines can be lifted with a small hoist and carried by trolley to a point below the next opening in the

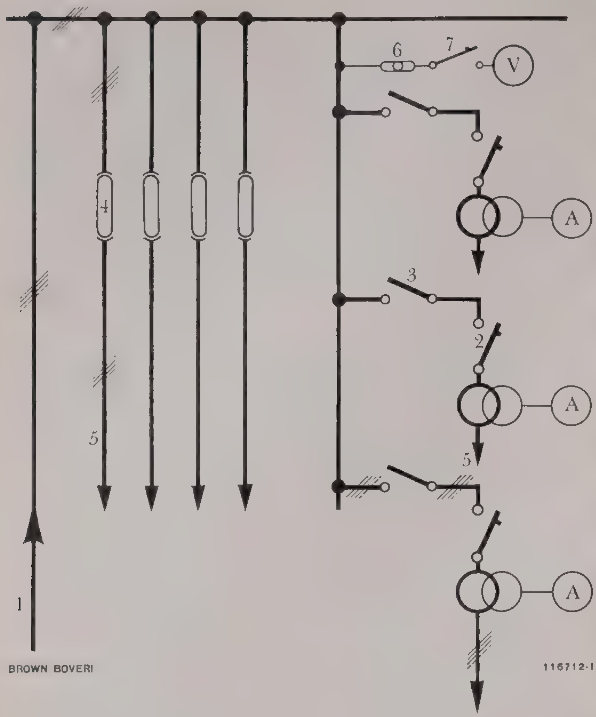


Fig. 9. – Circuit diagram of a local distribution board

The metal-clad board combines three 400-A feeders controlled by air-break circuit-breakers and four 250-A feeders with h.r.c. fuses, in a minimum of space. It can be installed with or without a concrete plinth.

1 = Incoming cable
2 = 400-A air-break circuit-breaker
3 = Triple-pole isolator
4 = Fuse
5 = Outgoing cable
6 = Triple-pole fuse for voltmeter
7 = Selector switch
8 = Voltmeter

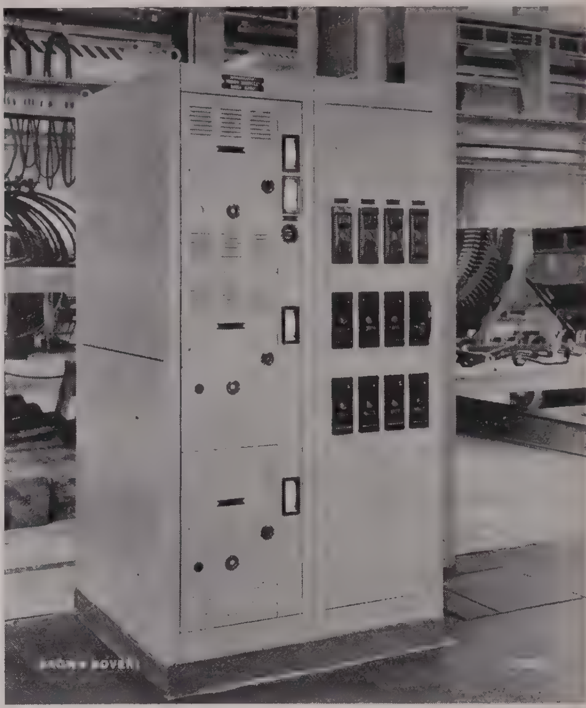


Fig. 10. – Metal-clad local distribution board

For free-standing installation in the workshops.

Fig. 11. – Converter room

In a specially ventilated room below floor level are all the converters for the machine-tool drives.

Cleanliness, freedom from dust, easy access to all terminals and easy replacement of a unit needing an overhaul are features of this arrangement.

floor, through which it can be lifted by the workshop crane up to the ground floor. A special ventilation system disposes of the heat generated; in summer it is dissipated to the atmosphere; in winter, on the other hand, it is used for heating the cellar. When the machines are adjusted for the first time, or after being repaired, the erectors in the cellar and at the distribution board can communicate with one another by means of portable telephones which can be plugged into permanently-wired sockets.

(KME) H. U. FREY

THE EQUIPMENT OF THE NEW TESTING STATION FOR ELECTRICAL MACHINES

62.006.2:621.313

On completion of the manufacturing process, the products of the factory pass to the testing station, in which their mechanical and electrical properties are checked before despatch, losses measured, characteristics plotted, and so forth. The test objects then have to run almost at their rated speed and be excited at the same time. Therefore power has to be supplied for driving and exciting the machines, and a means provided for carrying the current to the test-beds.

The test objects themselves are electrical machines of different kinds and sizes with widely divergent ratings. In view of this, and to allow for future developments, a number of synchronous alternators and d.c. generators, graduated in output power and voltage, had to be provided as sources of energy for the different tests. These generators are driven by induction and synchronous motors. In addition, two motor-generator sets have been provided, each consisting of a 2500-kW d.c. machine and a 6250-kVA synchronous machine, either which can act as the motor or the generator. When the d.c. machine is acting as the motor it is supplied through a pair of mercury-arc rectifiers. The larger motors (over about 500 kW) are connected to the 8-kV supply fed from the main substation. The small and medium machines run off the 380/220-V low-voltage network of the factory.

Some idea of the amount of equipment to test a synchronous machine is given by the simplified circuit diagram of the test set-up (Fig. 1) for the method known as "frequency start," which is used

P = Test object
B_1 = A.C. test-bench
B_2 = Rotor test-bench
G = D.C. generator
S = Synchronous generator
M_1 = D.C. motor
M_2 = Motor for 8 kV, 50 c/s
A = Starting transformer
E = Exciter
R = Mercury-arc rectifier
T = Rectifier transformer
L = Cross-bar selector
U = Voltage selection rack

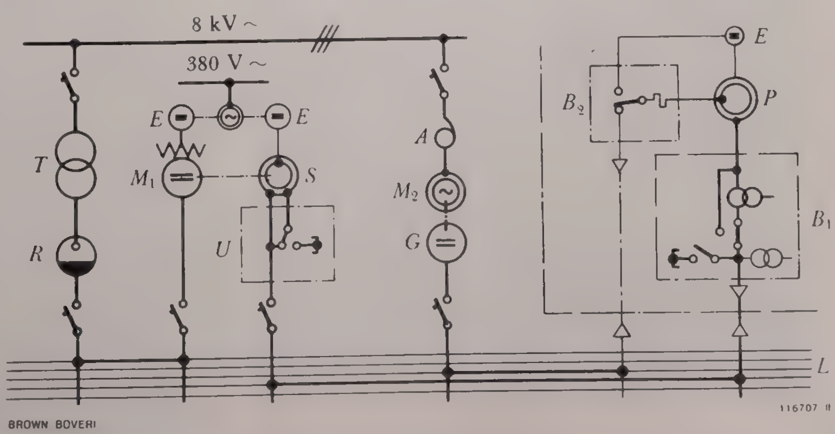


Fig. 1. – Schematic diagram of the test set-up for "frequency start" of a synchronous motor as test object

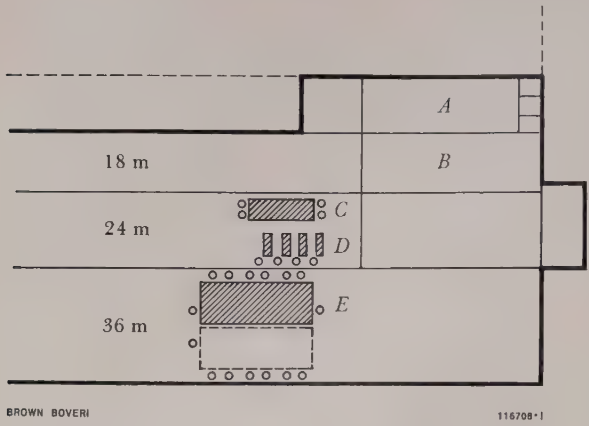


Fig. 2. – Layout of testing facilities in the factory

A = Machine room with motor-generators, transformers, etc.
B = Cross-bar selectors in the basement of the 18-m bay
C = Test-bed in the 24-m bay
D = Four test-pits in the 24-m bay
E = Test-bed (with future extension) in the 36-m bay
o = Test-benches fed from the cross-bar selector

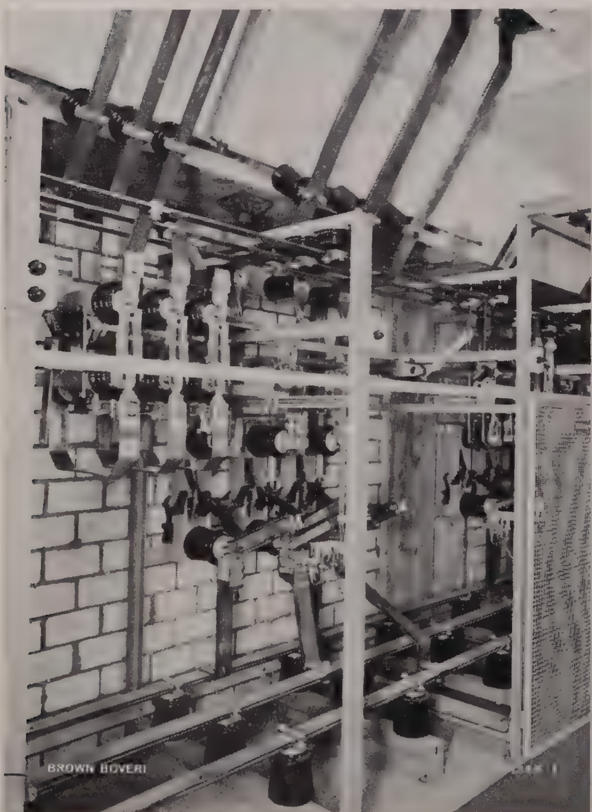


Fig. 3. – Distribution gear 1/24 kV for supply to test-benches

The isolators are pneumatically operated.

for accelerating synchronous machines to their rated speed. The test object is connected to the synchronous generator S, which is excited by its own exciter, whereas the excitation current for the test machine is supplied by the d.c. generator G. The synchronous generator S is mechanically coupled to a d.c. motor M, fed from a rectifier R.

All the main leads from the machines run to the cross-bar selector L, where they are interconnected by the horizontal bars. The leads leaving the selector run to a distribution board to which the test object is connected through the test-benches B_1 and B_2.

Fig. 2 shows the situation of the testing station. The machine-room A contains the motor-generators, transformers, rectifiers, with their control gear. At present the machine-room appears to be in a decentralized position; however, when the factory is extended, it will be in a position from which the length of all supply lines will be roughly equal.

In the cellar of area B are the cross-bar selectors and the 8-kV h.v. switchgear. The machines to be tested are assembled on the test-beds in the 36- and 24-m bays; these comprise a small bed C, four pits D and a large bed E, which at present only covers half the eventual area. Arranged round these stands are the test-benches, each of which has a three-phase connection for 24 kV, 2000 A which, when fed by d.c., can carry up to 3000 A; a second three-phase connection for 1 kV, 1000 A, and a 36-kV connection are also available.

The high-voltage distribution gear (Fig. 3), which is fed by eleven cables from the cross-bar selectors, is in the basement beneath the 36- and 24-m bays. The supply to the individual test-benches is controlled by isolating switches equipped with an earthing link, an intermittent control lamp providing the signal for operation of each isolator. For control of the motor-generator sets and for operating the circuit-breakers there is a system of control wires between the test-benches and a special cross-bar selector. Screened metering and control leads run to the oscillograph room, which of course is equipped with a well-appointed darkroom.

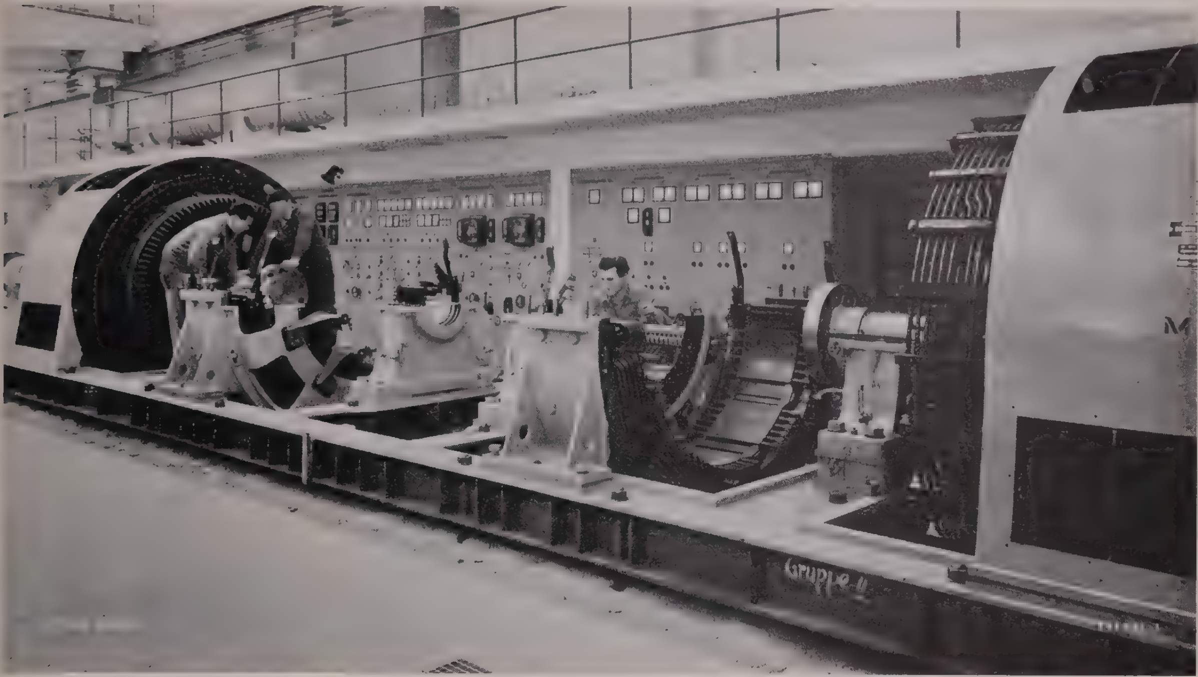
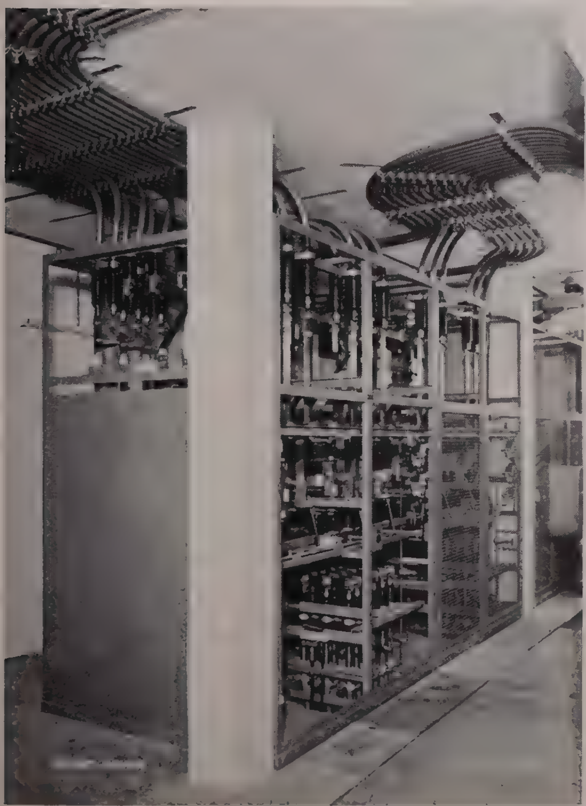


Fig. 4. – Part of the machine room

Being erected in the foreground is a motor-generator set with two d.c. machines rated 2500 kW each, and two synchronous machines for 6250 kVA each. In the background is the switchboard.



Machine Room

For the first phase the following equipment was installed in the machine room:

Three synchronous machines with ratings up to 6250 kVA,

Four d.c. machines up to 2500 kW,

Six smaller d.c. machines up to 320 kW,

Two mercury-arc rectifier sets producing d.c. voltages up to 5 kV and currents up to 6 kA,

One special transformer rated 12 500 kVA,

Two liquid resistors for loads up to 6000 kW,

Two auxiliary transformers, each rated 1250 kVA and a collection of small exciter sets.

Fig. 5. – Voltage selection rack for synchronous machines

The parts of the phase windings are connected to the upper part of the rack by cables. Four different voltages can be obtained by varying the connection with isolating switches.

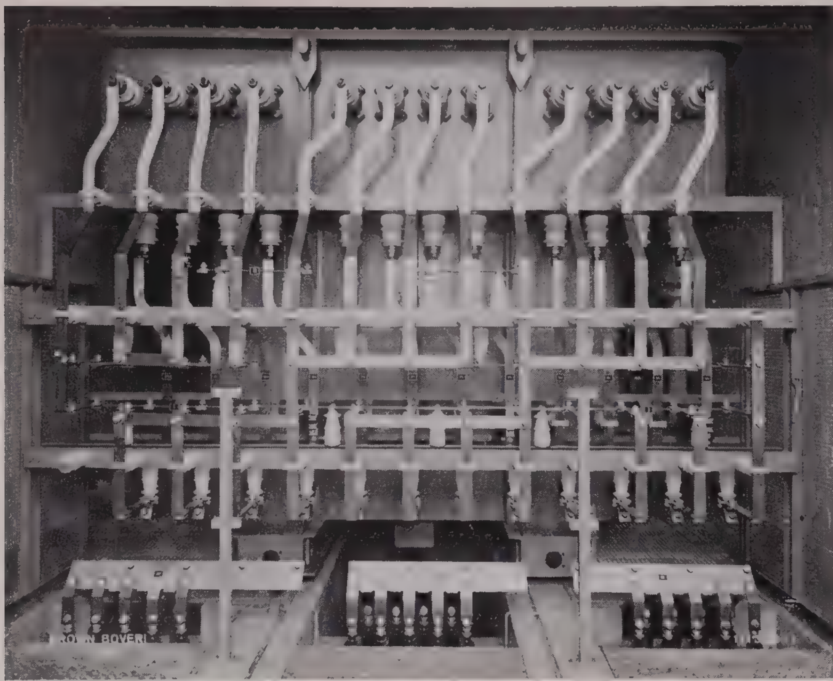


Fig. 6. – Low-voltage side of the special transformer rated 12 500 kVA

The four parts of each phase winding can be connected together in different arrangements. The same facilities exist on the high-voltage side.

Some of these machines, with their switchboards containing the supervisory instruments, control and synchronizing gear, can be seen in Fig. 4. Each machine is allocated a main circuit-breaker and protected by relays against the harmful effects of short circuits and overloads. The breakers are themselves connected to an emergency tripping circuit which, should the need arise, trips all the breakers and completely interrupts the supply. Minor disturbances are indicated by visible and audible alarms.

The three synchronous machines, which may run as generator or motor, are designed with each phase of the stator winding in two parts. When these are connected in series or parallel, and with the facilities provided by star or delta connection, each machine can be switched to any of four voltages in the ratio $1:\sqrt{3}:2:2\sqrt{3}$. This changeover is effected by pneumatically operated isolators in a rack (Fig. 5), the desired voltage being set with a selector switch on the switchboard. The rack also contains the thermal relays protecting the machines.

To match the voltage of the test object to the generators in the testing station there is at present a three-phase transformer rated 12 500 kVA. Each phase winding is divided into four parts on the h.v. and l.v. sides. By means of the cross-connection links visible in Fig. 6, and utilizing series, parallel, star, delta and zig-zag connections, it is possible to obtain 14 different voltages between 2 and 32 kV and 40 ratios. In every connection the transformer is protected against overload by thermal relays.

Cross-Bar Selectors and Distribution Gear

For practical reasons the cross-bar selector installation was divided into a "large selector" (Fig. 7) for 24 kV, with a current rating of 1000/2000 A three-phase or 3000 A single-phase, and a "small selector" (Fig. 8) for 1 kV with a rating of 1000 A. The selectors consist in principle of several horizontal three-phase busbar systems, one above another, which can be selected at random, and vertical three-phase busbar systems to which the machines or feeders are connected. The horizontal bars can be connected to the vertical bars by isolating switches (see Fig. 7), the majority of which are

Fig. 7. – Large cross-bar selector for 24 kV

The isolators are manually operated by switchrod. The command is given from the illuminated diagram by the flashing control lamps.

manually operated by means of a switchrod. This method was adopted because remote-controlled isolators would have occupied more space and, furthermore, because the infrequent nature of their operation did not warrant remote control. The horizontal bars themselves can be subdivided by several longitudinal isolators, thereby increasing the degree of occupation of the selector. Since the selectors involve a large amount of material, the connecting bars were made of aluminium, which proved less expensive than copper.

Allocated to every isolator on the selectors and the distribution gear is a control lamp which indicates by flashing when the isolator should be opened or closed. These lamps are controlled from an illuminated circuit diagram (Fig. 9). This indicates the state of connection at a given instant of the selectors and distribution gear, which are installed in three rooms in the basement and could not be supervised without this auxiliary means. This is a discrepancy circuit, which is so arranged that all those parts which are connected together or live,

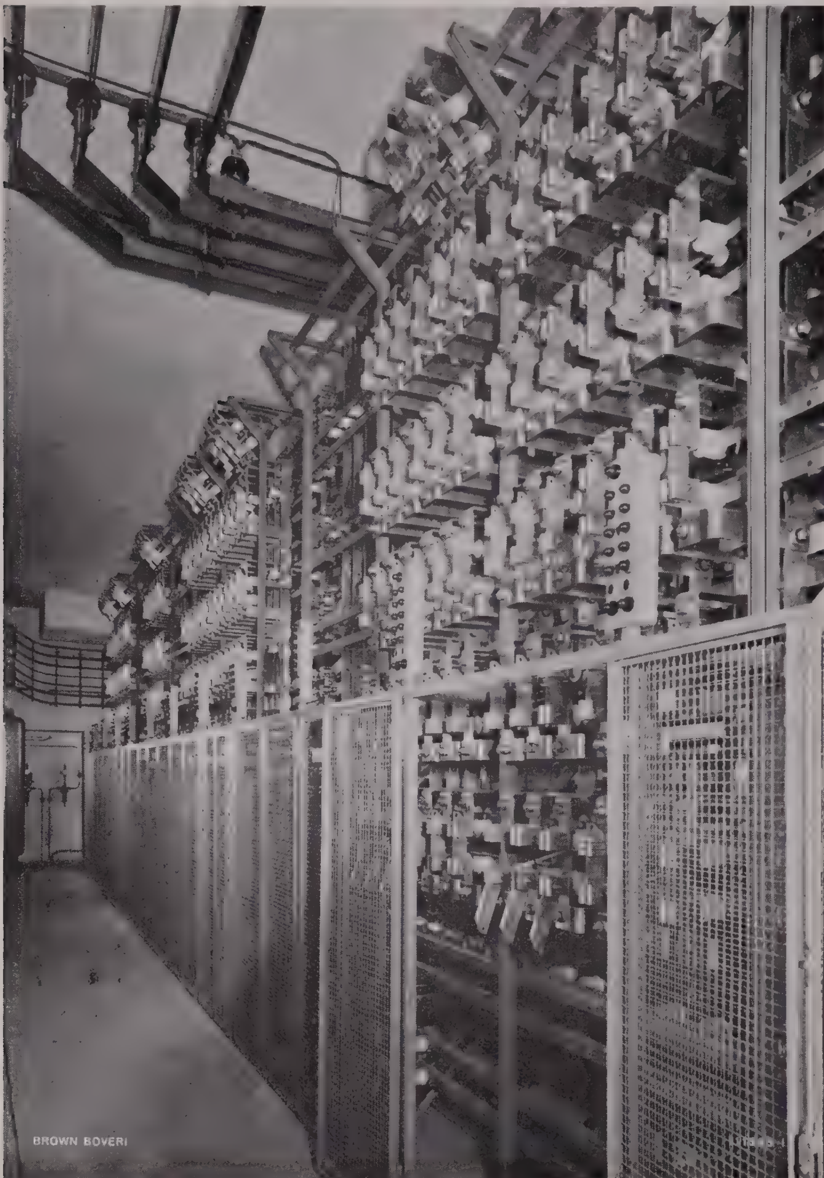


Fig. 8. – Small cross-bar selector for 1 kV

It contains 12 horizontal three-phase busbar systems, divided into four sub-sections. When fully extended it will be possible to connect 56 supply or load circuits to it.

light up. In addition, the position of the isolators is signalled by a green or red light. Every isolator has a push-button in the diagram. Pressing this button gives a visual command for the position of the isolator to be changed. When the command has been given, the indicator lamp on the panel and the control lamp at the switch continue to flash until the command has been executed or cancelled by pressing the push-button again. For control of the illuminated diagram and control lamps one two-way impulse relay and an auxiliary relay are required for each isolator. Sets of eight such relay combinations are mounted in a draw-out sub-unit and plugged in to a cabinet (Fig. 10). In the event of a relay becoming defective, the faulty sub-unit can be replaced by a spare. Location of the fault is facilitated by a built-in means of testing.

Special attention was paid to the cabling when the installation was planned (Fig. 11). On account of the large number of cables, which cannot be laid in ducts, it proved preferable to mount them on open-type racks; a specially designed clamp ensuring

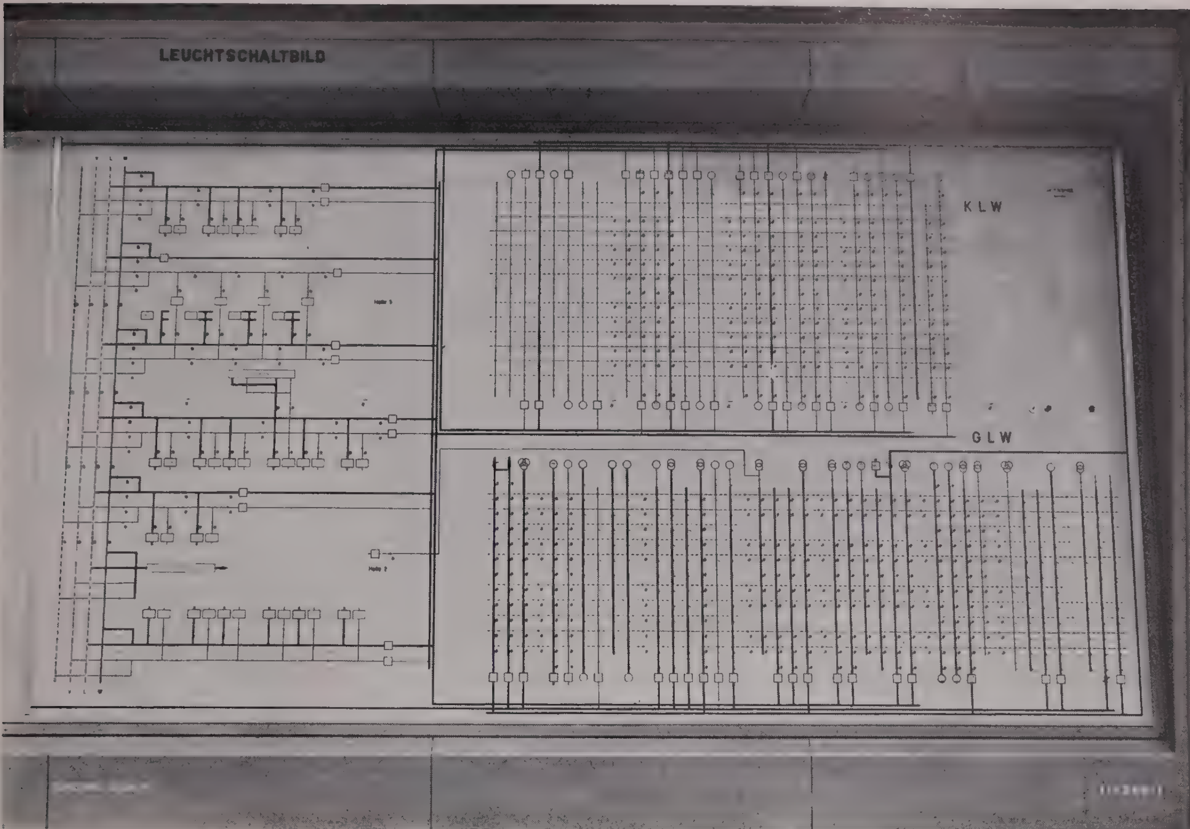


Fig. 9. – Illuminated circuit diagram of the testing station

The cross-bar selector (right) and the distribution system (left) are clearly visible. All occupied lines are illuminated, enabling the state of the installation to be checked at any time.

adequate air circulation between the power cables. The entire cabling system was planned in advance, i.e. the racks were prefabricated, so that they could be installed on site and the cables laid to predetermined points, exactly to the drawings. So far over 60 km of cable with cross-sections up to 300 mm² have been laid.

For the performance of tests and measurements, test-benches (Fig. 12) are available, containing all

Fig. 10. – Relay cabinet of the illuminated diagram

Each panel contains 11 drawout sub-units at the front and back. Thus 3500 relays can be accommodated in a minimum of space.

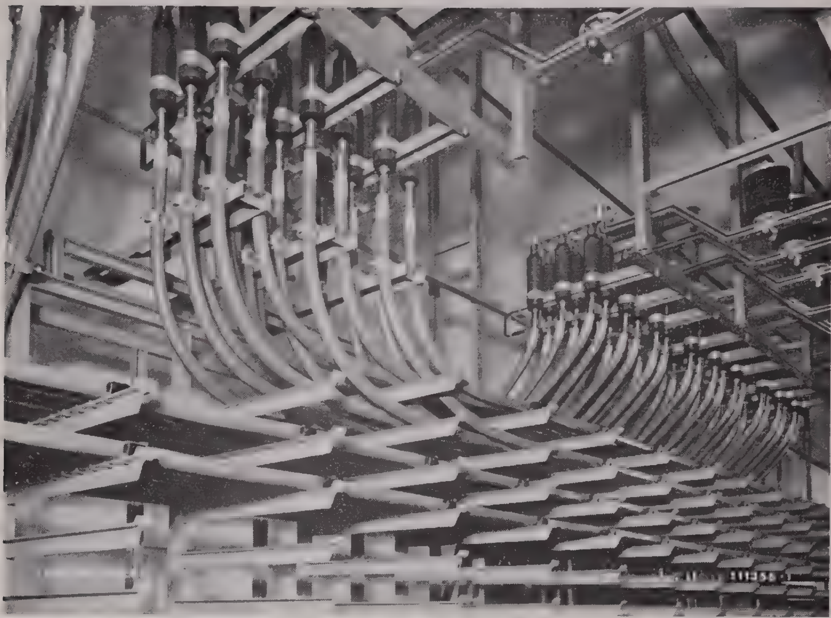


Fig. 11. – Outgoing cables from the large cross-bar selector

The single-conductor paper cables have a PVC sheath.

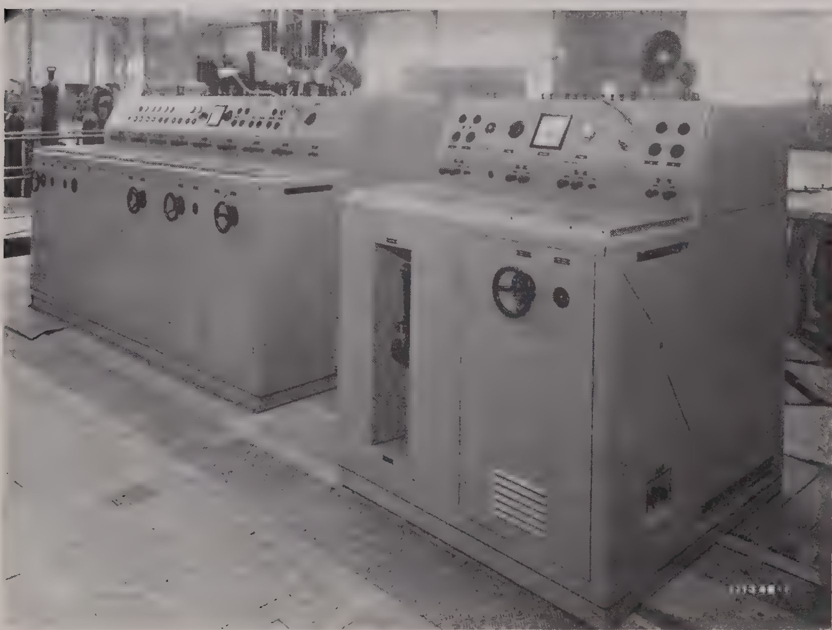


Fig. 12. – Test-benches for d.c. machines and excitation circuits of synchronous machines

They contain terminals for precision instruments and all the elements needed for controlling the generators.

the necessary control switches, indicator lamps, variable resistors, terminals for the connection of precision instruments, and so on. Providing direct speech contact with the personnel in the machine-house and the oscillograph room is a two-way communication system, which is powerful enough to overcome the noise made by the machines being tested.

Finally it should be mentioned that an amply dimensioned earthing system was provided for the entire installation, thus affording adequate protection to the test staff even in the event of very heavy short-circuit currents.

(KME) A. HAURI

LIGHTING

658.2:628.9

The excellent natural illumination afforded by the shell saw-tooth roof construction was a primary factor governing the decision to adopt this design. In the daytime the workplaces are uniformly lit without glare, owing to the incident light being from the north and due to the excellent transmission factor of the roof-lights, which in turn is balanced by the good reflection from the curved, unglazed part of the roof. For night-work artificial lighting of equivalent quality had to be provided. The specification for the lighting engineer entrusted with drawing up the scheme was therefore elaborate and included the following conditions:

Assuming the initial illumination with new equipment to be 250 lx (appr. 25 lm/ft^2), a permanent value of at least 180 lx (18 lm/ft^2) should be provided at a working height of 80 cm, allowing for reduction of the luminous output due to ageing of the fluorescent tubes, dirt on the fittings and deterioration of the reflection from the walls.

Special, local illumination must be provided on large machine tools on which the points to be observed by the operative, such as the tool, machined surface, measuring dial, etc., are obscured by superstructures.

Uniformity of the illumination is defined as permitting a deviation of —20% at the most unfavourable point.

The angle of incidence of the artificial light must correspond to that of the daylight, and when both sources are in use at a time, there must be no disturbing shadows or glare.

The lighting fittings must not obstruct the entry of daylight nor cast shadows on the underside of the roof. They must also be easy and quick to install and maintain at a considerable height.

How were these conditions fulfilled? Owing to the transverse arrangement of the saw-tooth roof construction with its light and shade effect, there is a strict uniformity of the contours perpendicular to the axis of the bays. In order not to disturb this impression the linear light-source provided by fluorescent lighting was adopted. The fittings are mounted on the underside of the cross-beams supporting the roof and harmonize well with the saw-tooth construction (Fig. 1). Due to their small projection, they afford the minimum clearance of 50 cm from the cranes running below, so that maintenance and tube-changing can be carried out from the crane without any auxiliary equipment.

White stove-enamelled reflectors improve the light output, permit uniform illumination of the bays and prevent glare when looking down the length of the bay with the rows of fittings running from side to side. The most economical lamp is the 65-W fluorescent tube for 4200 °K, which is mounted in two- and four-lamp open type fittings. At high mounting heights and with the small amount of dust produced in the factory, the fittings do not get dirty very rapidly. The stipulation regarding easy, safe erection at a considerable height is fulfilled by a newly-developed fitting in three parts (Fig. 2). When connecting up the lamps, attention was paid to even distribution between phases in order to overcome stroboscopic effect and to prevent a whole row of lamps going out in the event of failure of one phase. Individual tubes are connected to a separate supply as emergency and patrol lighting.

Part *A* of the fitting could be erected with the wiring during the initial rough building work and augmented to a complete lighting unit as soon as the risk of being damaged by water or scaffolding was past. Thus the final lighting scheme could be switched on at quite an early stage, eliminating the expense of temporary lighting with its attendant hazards from the electrical aspect, and inadequate illumination.

The lighting of the bays with the chosen form of fluorescent fittings complies with the stipulated conditions. After burning for about 1200 hours the tubes may be deemed to have reached their steady state; the illumination levels measured are within the specified limits.

Fig. 1. – The 24-m bay illuminated by 65-W fluorescent lamps, mounting height 15·8 m

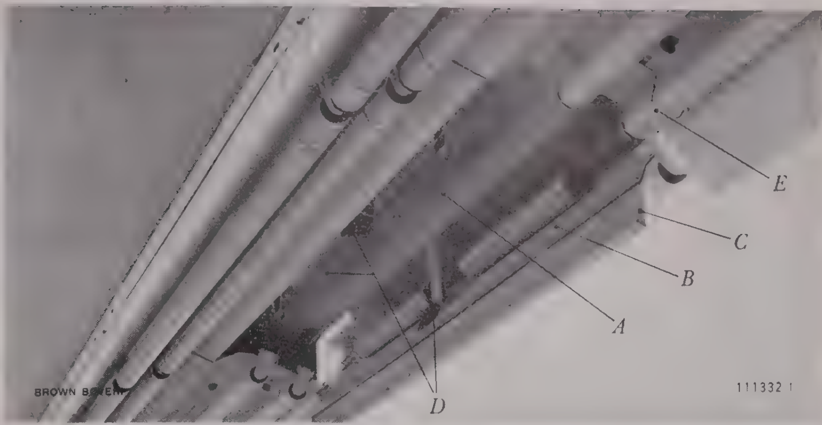


Fig. 2. – Three-part fluorescent fitting with four 65-W lamps

A = Backplate attached to concrete casing of girder; it contains the wiring and socket

B = Plate carrying control gear and lampholder; can be lowered to either side by means of quick-release hinges

C = Reflector, stove-enamelled white, with special fastening

D = Plug and socket. The circuit is closed automatically when parts A and B are joined together, thereby eliminating all possible contact with live parts.

E = Steel-wire loops to prevent lamps from falling out accidentally

Artificial lighting in all other rooms such as the electric substation and distribution centres, the boiler-house, the service passages, etc., many of which receive no natural daylight at all, received equally close attention. Good results have been obtained throughout with standard commercial fluorescent fittings.

(KME) H. R. RÜEGGER

CRANES

621.873

The basic methods of transportation in the workshops had to be taken into account at the very start of the layout planning because transport exerts a marked influence on the manufacturing costs of large machines.

The overall plan allowed the length of the bays to be made sufficiently long for the entire production process, from machining, through assembly and testing to despatch, to be situated under a single crane-track. The expensive, time-wasting off-line transports are eliminated, so that cranes may with advantage be adopted as the sole means of transport in the workshops. Dispensing with ground transport saves purchasing expensive special vehicles, and roadways can be made narrower, to the benefit of production area. The overhead crane thus changes from a simple lifting device with a restricted action radius to a means of carrying loads of 200–300 t over distances of several hundred metres.

The weights of the loads which the overhead cranes have to carry in the 36-m bay range from a few hundred kg to 300 t. Exhaustive investigations proved that by far the majority of individual objects weigh less than 60 t, and only the completed rotors and stators with their windings weigh between 60 and 300 t. At the individual workplaces in the machining and assembly sections, 80% of the workpieces, tools, fixtures, casings and winding parts do not weight 10 t. Thus it was obvious that a graduation of 10, 60 and 300 t was necessary for the capacities. But since a 300-t crane is much more complicated and difficult to erect, and has to be mounted much higher than two 150-t cranes, which do not cost very much more, and which can be coupled with a 300-t cross-beam, it was decided that this distribution would be adopted. Having had the cross-beam designed in such a way that a 150-t crane can also be coupled with a 60-t crane, the installation of a second 150-t crane can be postponed until such time as the factory calls for facilities for carrying over 200 t.

In the 24-m bay the graduation of the cranes was made 60, 40 and 10 t, while in the 18-m hall

for the construction of windings, cranes with capacities of 5 and 10 t are sufficient.

Apart from the load capacity, the lift and the clearance for the passage of objects above the largest machine tools had also to be stipulated as limits. For the 150-t crane a maximum height of 19·5 m above floor level was laid down for the hook, which also governs the height of the crane-rail. The two 150-t heavy-transport cranes are used less frequently than the lighter erection cranes, but must nevertheless be able to cover the whole length of the bay. The only practicable solution was therefore to allow them to run on a separate rail of their own. The 60-t cranes, in addition to localized tasks, also have to transport objects; they therefore have their own crane-rail too. Finally, at the lowest level, are the 10-t travelling-bracket cranes on either side of the bay, which cater for the individual workplaces.

This arrangement with cranes at three different levels affords all cranes a certain freedom of movement. In the 24-m bay there are two crane-rail levels, one for the 60-t overhead cranes and one for the 10-t travelling-bracket cranes. In the lowest bay, containing the winding shop, where material only has to be carried from one workplace to the next, a single overhead crane rail is sufficient, especially as numerous jib-cranes and hoists are provided for the individual workplaces.

In accordance with the required transport capacity, the numbers of cranes finally decided upon were as follows (Fig. 1):

36-m bay: 1 (later 2) overhead 150-t cranes, which can be coupled to carry 300 t;
2 overhead 60-t cranes, with an auxiliary trolley capable of carrying 10 t;
3 travelling-bracket cranes with a projection of 10 m, capacity 10 t.

24-m bay: 3 overhead 60-t cranes with an auxiliary trolley for 10 t;
2 overhead 40-t cranes;
1 travelling-bracket crane, 10 m projection, capacity 10 t.

18-m bay: 1 overhead 10-t crane

Winding shop: 2 overhead 5-t cranes with a special hoist mechanism for the transport of palettes.

The four travelling-bracket cranes can be rearranged on their three sets of crane-rails in only a few hours, without any electrical or mechanical modifications. They have loops above their centre of gravity and can be lifted out or inserted in any desired position with the aid of the 60-t crane.

The detailed technical investigation of crane problems, which was undertaken in 1956/7 in collaboration with the crane suppliers and the firm

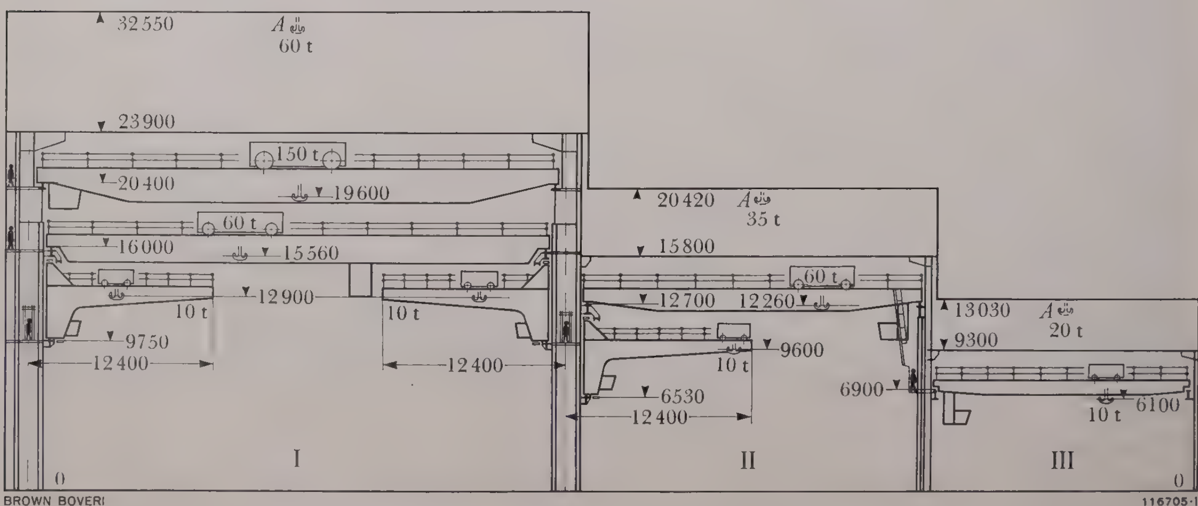


Fig. 1. – Section through the three factory bays, showing the arrangement of crane-rails, cranes and cat-walks

I = 36-m bay II = 24-m bay III = 18-m bay *A* = Hook in the roof for hoist used to erect the cranes

responsible for the steelwork, provided much valuable information: The effect of the wheel pressures experienced, the dynamic stresses imposed on the building by the cranes when running, the permissible tolerances for the length and width of the crane-rails, the influence of dilatation of the building, the cross-section of the various cranes and the access from the visualized catwalks, were factors which had all been clarified before the first projects, calculations and estimates were made.

As soon as the bays were partly covered the cranes could be taken into service and used for the final stages of the building work, in particular for placing the bed-plates.

Design of the Cranes

Box-girder construction

The box-girder design chosen for the bridges of all overhead and travelling-bracket cranes offers certain advantages over the conventional lattice or I-beam construction. Their depth is less, which is particularly important when they have to be installed at two or three levels. As a result, the height of the 36-m bay could be reduced by 2 m, thus saving 20 000 m³ of building space. In the box girders there is plenty of room for the electrical control gear, which is also accessible without risk (Fig. 2). Dirt does not collect on the smooth sides, and the top is easy to clean, an important factor above assembly and winding shops. The rigid box construction permits an auxiliary trolley of the travelling-bracket type, with a capacity of 10 t, to be mounted on one girder of a 60-t crane.

The cranes, which were manufactured by four different firms in and outside Switzerland, create a uniform impression and, with their smooth lines, blend well with the overall appearance (Fig. 3).

Mechanical equipment

A summary of the working speeds is given in the Table overleaf.

Since the vertical lifts are high and the distances to be travelled long, the working speeds had to be made correspondingly high; they exceed the normal figures for workshop cranes. Drives with a wide

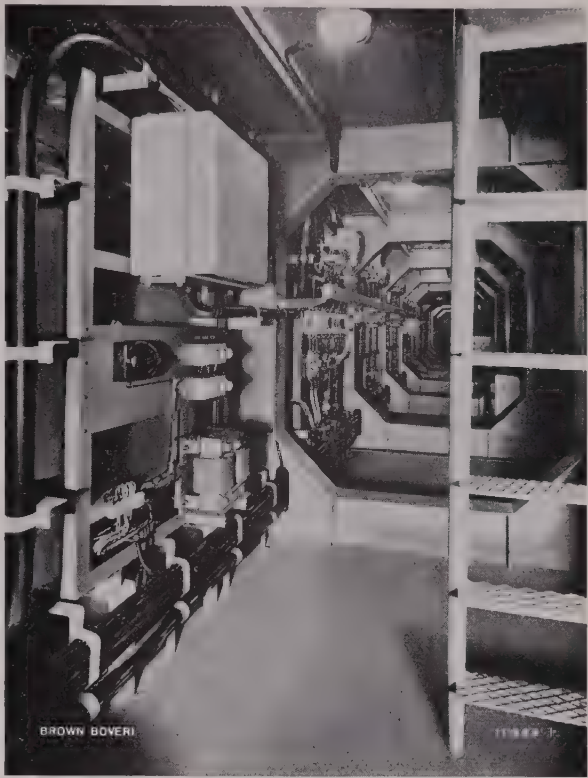


Fig. 2. – Electrical equipment in the box-girder type bridge of the 150-t crane

speed range are necessary if the most is to be made of the speeds.

Despite the cleanliness of the atmosphere in the factory, all gear-wheels except the low-speed pinions and spur-rings driving the bridge wheels, run in oil in totally enclosed gearboxes in order to minimize wear and maintenance. All plain bearings are connected to the central automatic lubricating system.

Electrical equipment

The provision of electrical equipment for 16 overhead cranes of different capacities and designs was a wonderful opportunity for the Company to try out some of their own drives with, in some cases, newly developed control systems.

All five 60-t hoists have Ward-Leonard drives with stepless control by a newly devised commutator controller. The two 40-t cranes in the 24-m bay, which have to be particularly quick and adaptable above the assembly beds, are equipped with three special Ward-Leonard sets—described

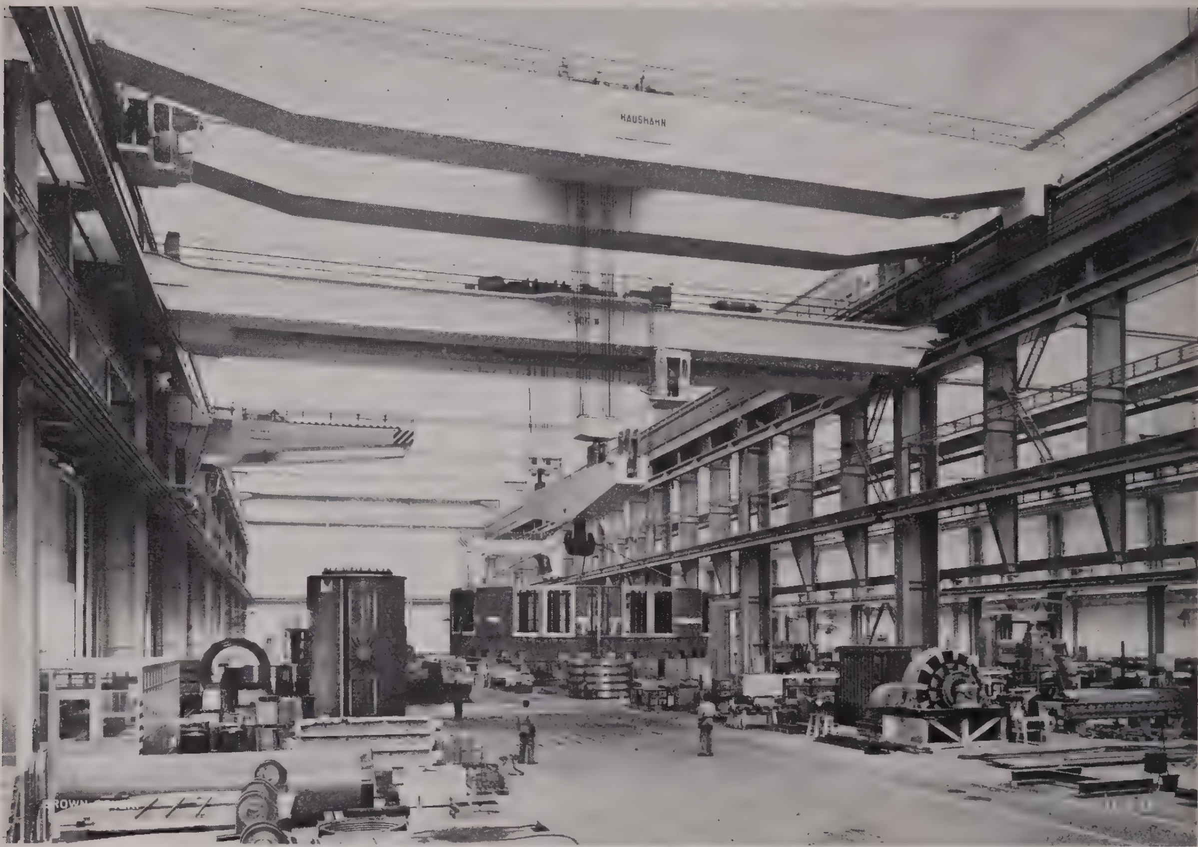


Fig. 3. – Combined operation by a 150- and 60-t crane with a 300-t cross-beam

Capacity of the two cranes together 200 t, correctly distributed by adjusting the position of the hook of the cross-beam.

Capacities and speeds of cranes and hoists

Crane capacity	Crane travel	Trolley travel	Hoist	Auxiliary trolley travel	Auxiliary trolley hoist
150 t	60 m/min	30 m/min	10 t: 2/10 m/min 150 t: 0·2/1 m/min		
60/10 t	50/150 m/min	8/40 m/min	0–10 m/min	8/40 m/min	1 m/min 4 m/min 20 m/min
40 t	0–150 m/min	0–40 m/min	0–10 m/min		
10 t	150 m/min	8/40 m/min	1 m/min 4 m/min 20 m/min		
10 t (travelling bracket crane)	120 m/min	8/15 m/min	1 m/min 4 m/min 20 m/min		
5 t (special crane)	150 m/min	8/40 m/min	1 m/min 2 m/min 10 m/min		

in a previous issue of this journal[1]—for their hoist, bridge and trolley. Apart from the operational advantages, the Ward-Leonard is able to manage with a good deal less control gear than a three-phase drive. The sets of control gear are identical, regardless of the motor rating, and therefore interchangeable, thus reducing the number of spare parts which have to be stocked. Instead of having to use expensive special speed-change gearing, it is possible to employ simple, cheap spur gears.

The limit switch for the hoist was incorporated in the control circuit in order to avoid the drawbacks of interrupting d.c. in the main circuit. As an extra safeguard, a second, emergency limit switch interrupts the excitation of the Ward-Leonard generator and the main circuit of the brake-releasing gear, causing the hoist brake to be applied instantaneously.

For the cranes with capacities up to 10 t and for the 150-t crane, which is less frequently in operation, three-phase drives are more economical. With the aid of a supplementary electro-hydraulic control device a speed ratio of 1 : 5 can be attained. An interesting combination of different lifting speeds, obtainable with simple electrical and mechanical means, is to be found on the 150-t crane. By providing a range of 0·2 to 1 m/min with 150 t and 2-10 m/min with 10 t, this heavy-duty crane can also perform the duties of a workshop crane. Its high-speed stage is automatically protected against overload by a pressure transducer. Similar safeguards against overload are fitted to the hoists of all the travelling-bracket cranes, because only a slight overload can cause serious damage to the crane and the building.

The crane-driver has a suspended cabin with an all-round view of the load and other cranes. The high viewpoint, the high speed and presence of other cranes on the same track demand the utmost concentration from the driver. For this reason close attention was paid to the design of the cabin, in order that the driver may control the crane with two levers, sitting and with his arms rested. Since communication with men on the ground giving the commands for operation or load-handling is not reliable with the usual hand signals, the 60 and 150-t cranes in the 36-m hall are equipped with Brown Boveri radio-telephones, which permit excellent two-way speech communication. All drivers' cabins have the same layout of controls so that drivers can change from one crane to another at any time without special instruction.

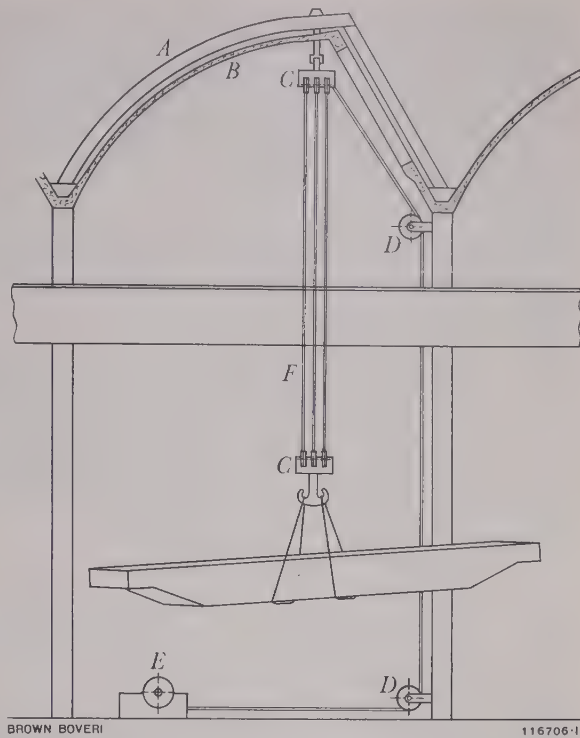


Fig. 4. – Method used to raise the top crane in each bay

A = Girder supporting the hoist
B = Roof shell
C = Hoist block
D = Diverter pulleys
E = Winch
F = Capacity:
60 t in 36-m bay
35 t in 24-m bay
20 t in 18-m bay

The high speeds and the heavy weights of the cranes themselves and their loads would inevitably result in serious damage to the building if the crane were to run full tilt into the end-stops. As unlikely as this kind of accident may seem, the necessary safety precautions have nevertheless been taken. The spring buffers can only absorb the momentum of the loaded crane safely when the speed is reduced to one-third of the normal figure. To ensure that this limit is automatically observed, a limit circuit is provided in which a centrifugal switch on the drive motor is in parallel with a reversing switch located

[1] A. SCHENKEL: Ward-Leonard Drives for Modern Cranes. Brown Boveri Rev. 1959, Vol. 46, No. 8, p. 443–50.

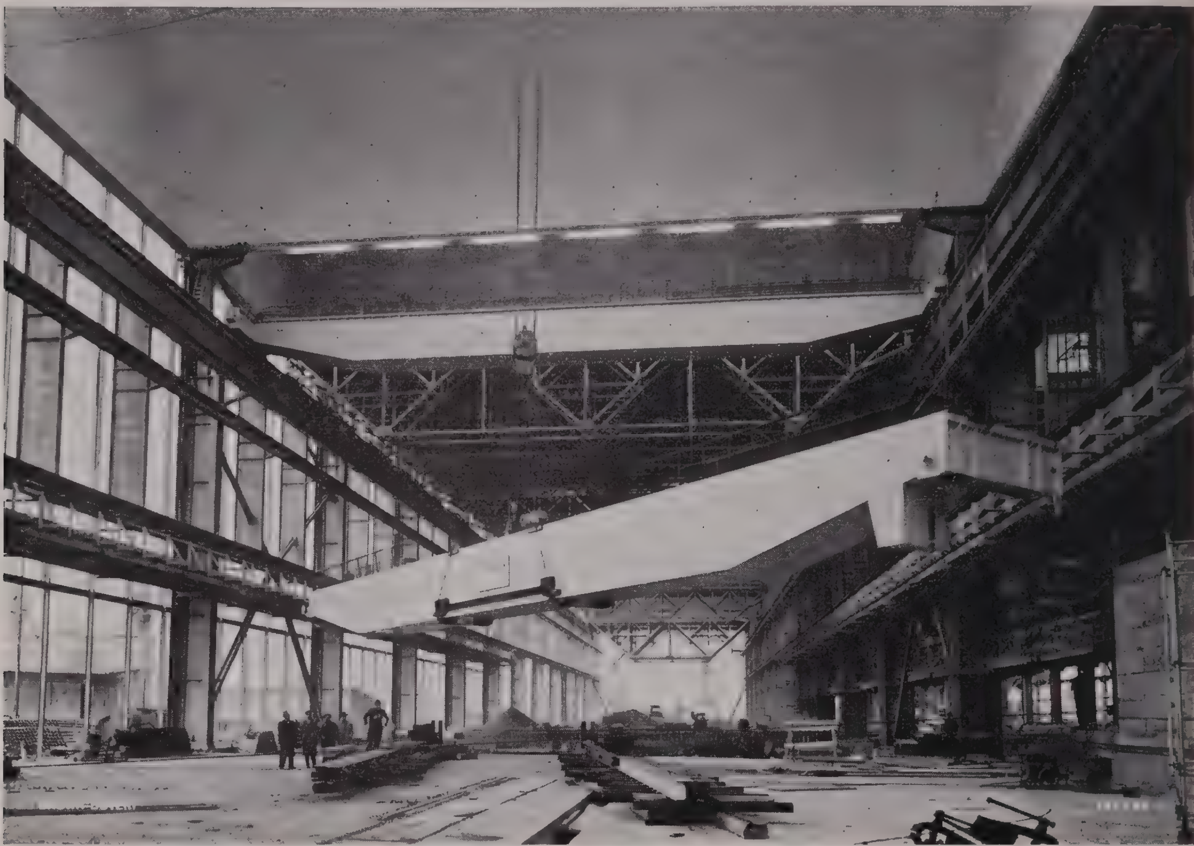


Fig. 5. – Lifting one of the two 60-t bridge girders of the 150-t crane
with a 10-t electric winch and 8-rope block and tackle.

a certain distance from the end of the rail; this switch has a lever which strikes a bar and operates. If at this point the crane is travelling at more than one-third of its rated speed, both switches are open and the drive is disconnected. The run-out distance was made sufficiently long to allow the crane to run unbraked and still not strike the buffers at more than the permitted speed. If the driver runs into the end zone at reduced speed, he can continue unhindered up to the buffers; but he then starts up at full speed in the reverse direction.

Erection of the Cranes

The erection of the cranes, whose heaviest parts—the bridge and trolley—may weigh up to 60 t and which have to be raised a height of 20 m and placed on the crane-rail ready for operation, is not an every-day occurrence. The concrete roof section, reinforced by a steel yoke, can carry an isolated load, suspended from the crown in the middle of the bay, of 60 t in the 36-m bay, 35 t in the 24-m bay and 20 t in the 18-m bay. With an auxiliary hoist on the roof the upper block of the hoist, complete with the ropes, was raised and anchored. A 10-t electric winch with diverter pulleys then lifted the two halves of the crane bridge, with wheel-box attached separately, in a space of a few minutes and placed them on the crane-rail, mobile and ready for connection to one another (Fig. 4 and 5). With this simple procedure, the cranes could be given their final coat of paint while still on the ground, and erected with only slight scratches, which could easily be made good without any scaffolding. The lower-level cranes were raised in a similar manner with the aid of the 150 or 60-t crane running above. The suspension arrangement in the roof was left in position, allowing a new crane to be lifted directly from the transport roadway, or trolleys and other components to be dismantled and lowered for repair.

(KME) G. HERRMANN

SOMETHING OF THE HISTORY OF THE BIRRFELD

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Birrfeld, the area in which the new Brown Boveri factory now stands, is the tongue of land between the river Reuss and the Aare before the two join. It is a flat area formed by the terraced rubble left by the flow of glaciers during the last Ice Age, and covers about 10 square kilometres. Its northern boundaries are the Scherzberg and the Eitenberg, two spurs of the Jura chain. Likewise the Kestenberg, which overlooks the southern extremity of the area, is geologically the continuation of a limestone rib of the Jura, known as the Gislifluh. This begins east of the Aare break at Wildegg and disappears beneath the rubble mass at Brunegg. Towards the west the deposits of gravel are relieved by less rocky loam and clay. In the east, where the Birrfeld descends towards the river Reuss, the terraces created by the glacier flow are most pro-

Fig. 1. – Perched high on the eastern end of the Kestenberg, visible from all over the Birrfeld, stands Brunegg castle, founded by the Habsburgs in the 13th century

Fig. 4. – The parish church in Birr was erected in its present form in 1662

as an independent protestant parish church for the six neighbouring villages: Birr, Birrhard, Brunegg, Lupfig, Scherz and Schinznach-Bad. This is still the territory covered by the parish of Birr. The church was built in its present form in 1662. The foundations of the original late-Gothic church were brought to light in 1934 within the present building. In 1955 the church was presented with a new peal of bells. The largest of these weighs 1225 kg and was presented by Brown, Boveri & Co. Engraved on it is the inscription "For other foundation can no man lay than that is laid, which is Jesus Christ" (1.Cor. 3, 11). Two of the three bells from the old peal now stand beside the Pestalozzi monument. The larger bell, of Gothic origin, dates back to 1400 and is of great artistic and cultural value. Around the top it is inscribed "*o rex glorie kriste veni nobis cum pace*" (O Lord of Glory, come to us with peace) together with the Old High German words "grim beia ich," which may be translated by "Anger I proclaim," because it is believed to have been used as the bell announcing sittings of the local court of law.

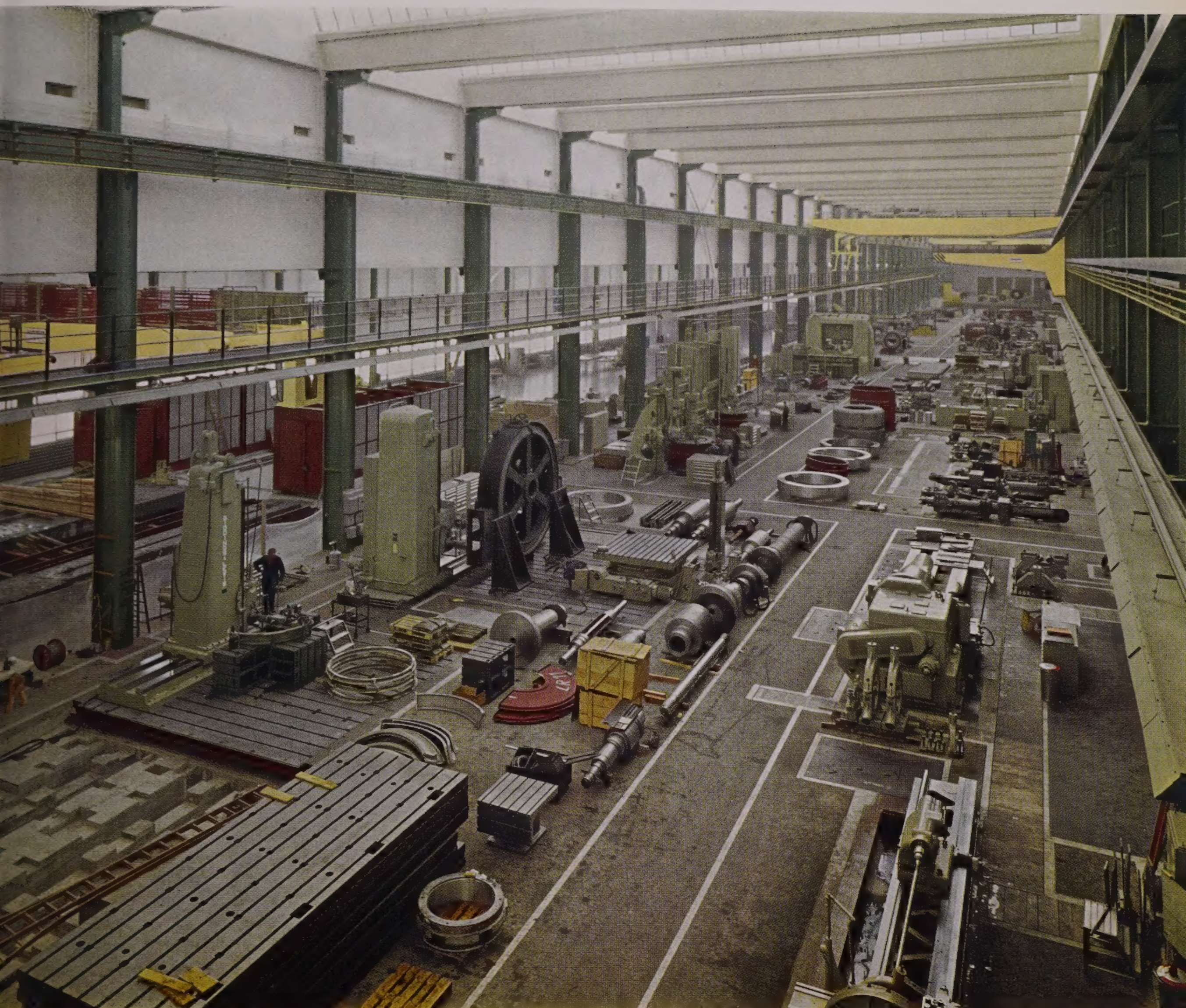
A historical curiosity worth mentioning are the 22 graves of members of the Bourbaki army in the churchyard. These are the resting places of members of the French army of 85 000 men who sought refuge in neutral Switzerland when being attacked by the advancing enemy during the Franco-Prussian war in 1871. These men were exhausted from hunger and exposure, and were taken care of in many villages and towns in the area. Some of them were sent to Bad Schinznach to reconvalesce, but 22 of them died in the spring of 1871 and were buried in the cemetery of Birr church. French visitors to Bad Schinznach contributed to a memorial for their compatriots. It was executed in 1899 in bronze by the Alsatian sculptor Frédéric-Auguste Bartholdi, and takes the form of a victorious angel. Incidentally, Bartholdi is also the creator of the world-famous Statue of Liberty in New York harbour.

Closely connected with Birr is Lupfig, likewise an old farming community, which shared the historic past of its neighbour. The true picture of the village was seriously changed by a disastrous fire in 1900, in which most of the upper part of the village was destroyed. As in Birr, most of the houses were of the uniform thatched type up to the first world war. The last thatched roofs disappeared from Lupfig in 1946.

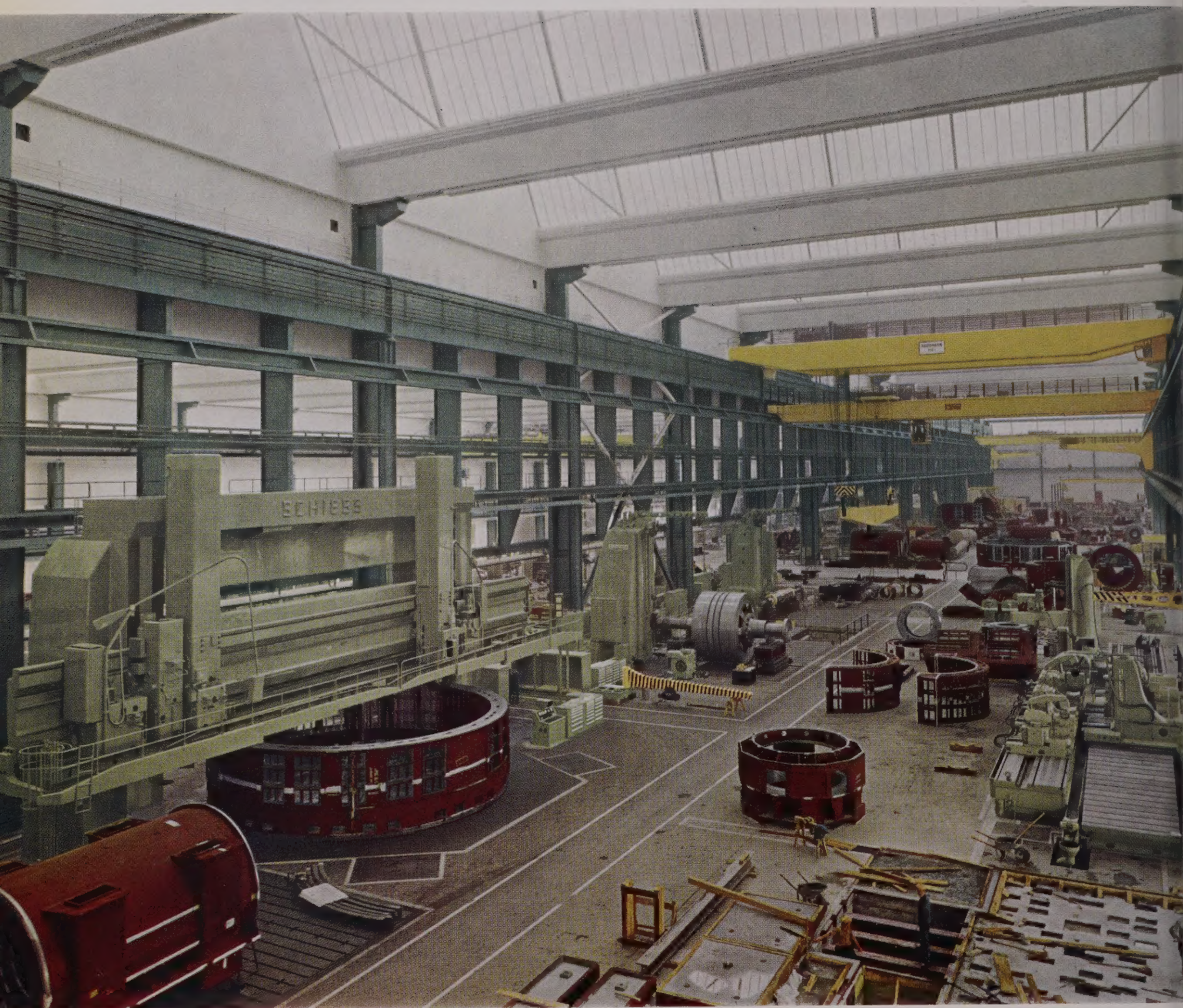
Whereas up to twenty or thirty years ago the inhabitants of the Birrfeld were almost exclusively engaged on agriculture, there has been a marked tendency in recent years for youth to go into industry. The numerous small-holdings have now largely vanished, the fertile land now being divided among about half a dozen large-scale farmers. With the entry upon the scene of industry, the inner and outward appearance of the area will change completely in the course of the next ten years or so. Where today hardly 3500 persons live, dispersed among several small communities, there will probably be a town with up to 40 000 inhabitants. The regional planners, who are busy with their long-term ideas, already have quite clear conceptions of this town and have depicted their visions in the form of a model. Already going beyond the scope of the model, Brown Boveri will soon be building accommodation for the workers and staff of their new factory.

But nowhere does time stand still, not even in the Birrfeld. The busy hands of its inhabitants turned the "dry, barren heath" into a blossoming, fertile landscape. The energy and confident labour of its future inhabitants will also govern the future of the Birrfeld, which has already begun with the entry of industry upon the scene.

(KME) E. STÄUBLE



View in the 24-m wide workshop where electrical machines of medium outputs are assembled. The majority of the machine tools for this bay are already installed. In the left-hand bottom corner of the picture are sole-plates ready for erection



View of the 36-m main shop where very large electrical machines are assembled. On the left is the casing of a hydrogen-cooled turbo-alternator, behind it on the vertical boring and milling machine is the welded stator frame of a 60-MVA hydro-electric generator. Right, in the foreground, preparing the foundations for another machine tool

BROWN BOVERI

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